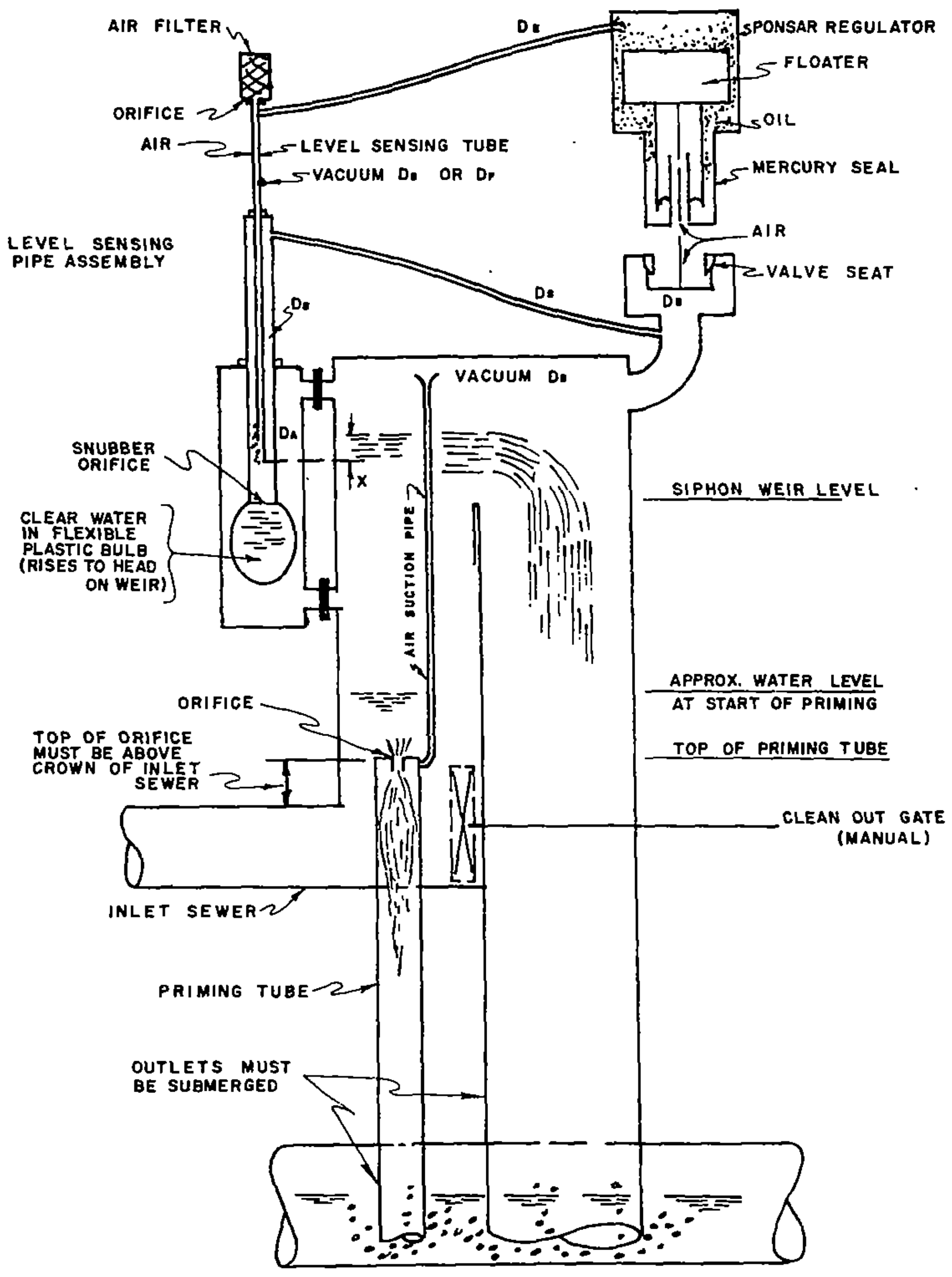
FIGURE 2.12.1



PONSAR SIPHON

Courtesy Degremont S.A. and New York City, N.Y.

be drawn out through the downdraft tube and the water level will likewise rise in the downdraft tube.

2.12.2 Design of Priming Pipe (Based on data furnished by Degremont Corp., Paris)

Operation of the priming pipe is similar to a hydraulic compressor in which hydraulic power is converted to compressed air power.

Let: Absolute suction pressure at inlet = P_a (ft. of water)

Discharge pressure due to submergence at outlet = P (ft. of water)

Ratio of pneumatic to hydraulic power = u

Air compression rate = $(P_a + P)/P_a$

Output ratio of volume of air to volume of water = Q_a/Q_w

Available operating hydraulic head = h

Then: $u = (34Q_a)/(h\,Q_w) \times \log_e (P_a + P)/P_a$

For priming tubes the ratio of (air power)/(water power) may be estimated at 40 percent.

The hydraulic air compressor may be considered the reverse of an air lift and the design could proceed on that basis. The relationship of available operating hydraulic head, depth of submergence at outlet, specific gravity of air plus water mixture and hydraulic losses may be expressed as follows: (based on "The Control of Water" by Philip A. M. Parker.)

$(h + d)/(1 + K) \quad -d = h_f + h_v$

Where:

Available operating hydraulic head = h (ft)

Depth of submergence at outlet = d (ft)

Losses due to friction = h_f (ft)

Misc. other head losses = h_v (ft)

$K = (34Q_a)(dQ_w) \times \log_e \times (34+d)/34$

In the above value of "K" the air supply is measured in cu. ft. at atmospheric pressure. In this connection it may be pointed out that 1 (1 + K) is the specific gravity of the air + water mixture.

The preceding considerations provide a basis for estimating the air discharge rate, "Q_a" and, correspondingly, the time required to produce the desired vacuum conditions and the duration of back-up conditions in the incoming sewer.

The use of an orifice of smaller diameter than the priming pipe is necessary to provide an initial jet at downdraft with partial vacuum around the jet below the orifice.

Control of Flow Through Siphon

The rate of flow through a siphon can be controlled to any desired limit below the rate of flow at full siphon action, by introducing air into the siphon chamber at a regulated rate so as to maintain the desired partial vacuum for design conditions. This objective can be accomplished by use of a vacuum pump with suitable provisions for its operation in relation to desired flow control. Either electrical power, or hydraulic power by water under pressure must be provided to operate the air pump.

An automatic, self-regulating device with appropriate accesories described as the Ponsar Regulator is available to perform the function of vacuum regulation inside the siphon without the use of external power.

The Ponsar Regulator is essentially a vacuum-operated, float-balanced air valve which responds to the vacuum intensity and liquid level in the siphon chamber. The air valve is normally closed. It opens only to admit air in response to siphon conditions, as required to maintain the design flow and to prevent vacuum intensity in excess of desired design conditions.

The Ponsar Regulator consists of two basic elements: (1) A regulator valve which has a floater at the top of the valve immersed in oil over a mercury seal and a connecting shaft to an air inlet valve at the bottom; and (2) a level sensing pipe assembly with its lower end inside a separate chamber where a water-filled plastic bag is attached at the bottom. A level-sensing tube is installed inside the level-sensing pipe. The top of the pipe has an airtight joint where the level-sensing tube passes to the outside. As the water level within the siphon rises due to increased vacuum conditions, the liquid in the plastic bag is compressed, raising the water level in the pipe until the mouth of the level sensing tube is submerged. Filtered air is drawn in through an air filter and a small orifice at the top of the level sensing tube. The quantity of air drawn in is dependent on the water level in the level sensing pipe. This air lowers the vacuum pressure in the level sensing tube and the reduced pressure is transmitted to the top of the floater. The lower part of the air valve has a tube connection to the top of the level sensing pipe, thereby maintaining vacuum conditions therein equal to the vacuum in the siphon. As the vacuum pressure increases, the water level in the siphon rises above the design level, the air valve is subjected to a higher vacuum intensity than the top of the float, the air valve descends, its air ports are opened, and air is admitted to the siphon until the vacuum intensity is reduced and the design flow level is restored.

For purposes of discussion, the vacuum suction pressure at the top of the float is designated D_f and the vacuum suction pressure in the siphon as D_s. If the air inlet orifice at the top of the level sensing tube becomes clogged or its diameter is too small to admit sufficient air, then D_f will approach D_s and the air valve will open, because the buoyancy of the floater is greater than the weight of the moving valve element by a vacuum pressure differential, X, equivalent to a predetermined value. Whenever D_s exceeds D_f plus X, the air valve opens. The air valve remains closed as long as D_s is less than D_f plus X. The level sensing tube is movable and can be reset to desired design elevations. A separate indicator gauge is provided to show the water level in the siphon, which permits setting the level sensing tube at the proper elevation.

Problems of Siphon Operation

Since siphon operation is governed by partial vacuum conditions, some air will always remain at its summit. It also can be expected that additional air will be introduced by release of entrained air in the incoming waste water flow and by direct inward leakage at siphon joints and connections. However, air admitted by the regulating device will be the major air component.

Changes in upward velocities of the siphon flow may cause some surging at the water surface. It is impractical to completely suppress surging effects inside the siphon, except as can be accomplished by a snubber provided in the level-sensing tube above the clear water container.

In general, the lower range of operation, to about 1/3 of the full siphon capacity, will be unstable in action because of inadequate air evacuation at low flows. Greater stability will prevail when the siphon operates at 2/3 or greater capacity.

Flow conditions in the incoming sewer will be affected by operation of the siphon. In order to prevent entry of air from the incoming sewer to the upflow branch of the siphon, entry to the siphon must always be submerged. The top of the priming tube therefore must be set higher than the inside top of the sewer connection entering the siphon. Additional backup in the sewer will be caused by the head required above the orifice to establish effective air evacuation and necessary vacuum conditions. The backup of flow will result in a temporary reduction of flow velocities and temporary storage in the incoming sewer. After appropriate vacuum pressures are established in the siphon, the flow in the sewer will be restored to normal levels related to submerged inlet conditions.

SECTION 3

DESIGN GUIDELINES FOR TIDE GATES, THEIR CHAMBERS AND CONTROL FACILITIES

CONTENTS

3.1. General Information

3.1.1 Principle

Tide gates, also called backwater or flap gates, are installed at or near sewer outfalls to prevent the back-flooding of the sewer system by high tides or high stages in the receiving waters. Tide gates are hinged at the top and are designed to permit discharge through the gate with small differential head on the upstream side of the gate and to close tightly with small differential head on the downstream side of the gate.

3.1.2 Application

Tide gates are required at all sewer outfalls where there is a possibility of the sewer system being flooded by a rise in the level of the receiving waters.

In combined sewer systems without regulators, tide gates usually are installed at the end of the outfall. The outfall is terminated in a concrete headwall and the tide gate is mounted on the face of the wall. This tide gate location very often makes maintenance work difficult, particularly if the gate is partially submerged. In this case, boats may be required to carry out normal maintenance procedures.

When regulators are constructed on combined sewer systems, consideration should be given to locating the tide gate in a chamber adjacent to the regulator chamber. This has several advantages. The gate will be easier to service than when located in or near the water. The gate can be inspected in conjunction with maintenance visits to the regulator. Provision can be made in the chamber for use of stop logs downstream of the flap gate so that the gate can be serviced "in the dry" if necessary. A further advantage of installing the gate in a chamber is that motorized equipment can be operated directly over the chamber for use in maintaining or replacing the gate.

The chamber width should provide a minimum of 6 inches clearance between the tide gate and the wall. When multiple gates are used the post or column between the gates should have a minimum width of 2 feet.

Shaft and surface openings should be provided with dimensions of about 1 foot greater than those of the gate. When the gate is always partially submerged it may be desirable to install two gates in series to provide a safeguard against one gate being clogged open. In the latter case the chamber can be enlarged to permit this series installation of gates.

3.1.3 Description

Tide gates are available in three types depending on the material used for the flap as follows: (1) Cast iron; (2) pontoon; and (3) timber.

Tide gates with cast iron flaps are available within circular, square or rectangular shapes. Circular flaps range from 4 to 96 inches in diameter. Sizes available from one manufacturer are given in Figure 3.1.3.1 Square and rectangular cast iron tide gates are available in sizes ranging from 8 inches square to 96 inches square. Sizes available from another manufacturer are shown in Figure 3.1.3.2.

Pontoon flap gates are fabricated of sheet metal to form a number of air cells. This increases the buoyancy of the gate and enables it to open under a smaller differential head than is possible with a cast iron gate, particularly 48 to 120 inches, as shown in Figure 3.1.3.3. Square and rectangular shapes are available in sizes ranging between 48 inches square to 120 inches square as shown in Figure 3.1.3.4.

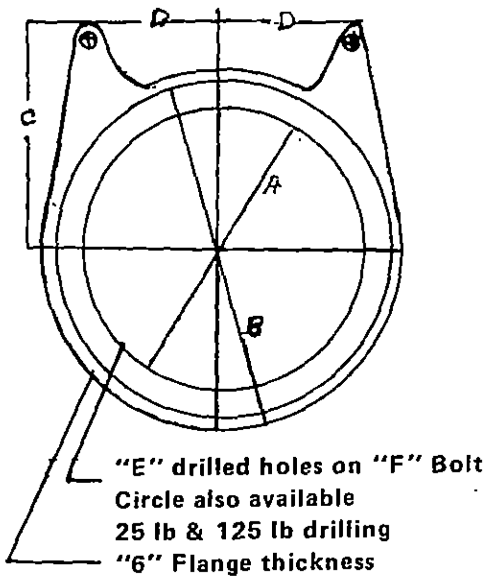
Type 316 stainless steel is used for large pontoon fabrications. It is weldable, has physical properties comparable to mild steel, and has satisfactory corrosion resistance.

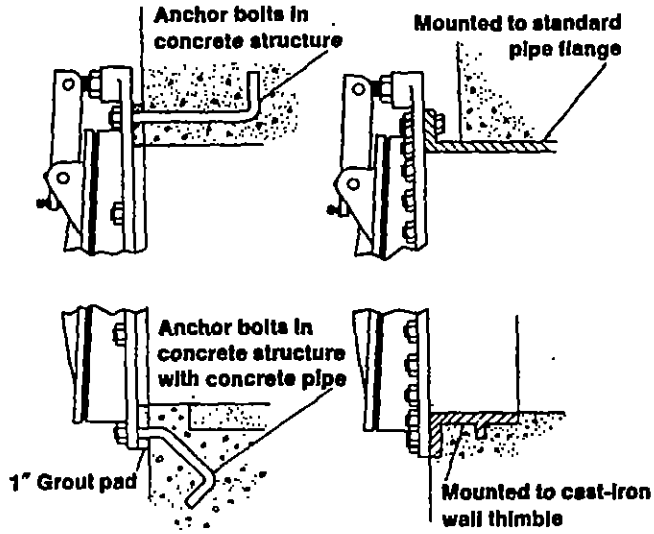
In recent years, there has been a revival of timber tide gate flaps. This is due in all probability to the pollution in major harbors. Teredos and ship worms cannot live in polluted water. Therefore, the timber will have a long life. Warping is partially prevented by the use of strong backs bolted to the timbers. These are pieces of railroad track that are hot dip galvanized after all machining is completed. Timber gate leaves are not as tight as the metal tide gates because it is difficult to seal the space under the metal seat band between the timbers.

Timber gates are available in the same sizes as the larger size cast iron square and rectangular gates. One manufacturer's models are shown in Figure 3.1.3.5. Creosoted yellow pine is frequently used in timber gates. Recently greenheart timber has been introduced. This wood grows only in British Guiana, requires no wood preservative treatment and is resistant to wood-destroying fungi. It is extremely dense, weighing approximately 70 pounds per cubic foot, and is well suited for flap gates as it requires little additional weight to offset buoyancy Greenheart also is more resistant to seasoning splits and checks than common structural woods, it machines well and resists distortion well. The following table compares the working stresses for greenheart and other structural woods.

FIGURE 3.1.3.1

CAST IRON CIRCULAR FLAP GATES





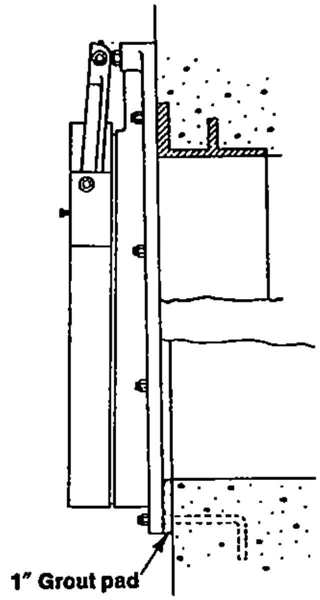
METHODS OF INSTALLATION

TABLE OF DIMENSIONS (Inches)

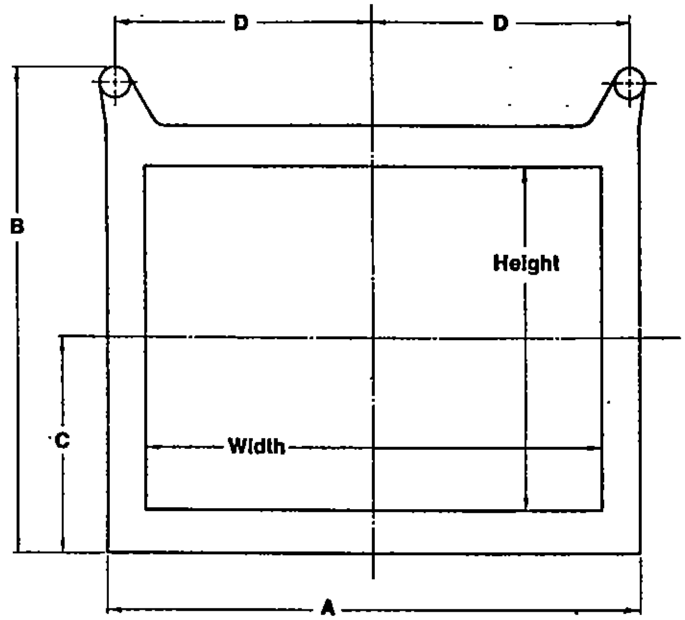
A—Dia.	B	C	D	E	F	G
4	9	5 5/16	2 3/4	4	7 1/2	3/4
5	10	5 5/16	3 1/4	4	8 1/2	3/4
6	11	5 5/16	3 1/2	4	9 1/2	3/4
8	13 1/2	6 3/4	4 3/4	4	11 3/4	3/4
10	16	8 1/4	5 7/8	4	14 1/4	7/8
12	19	9 3/4	6	4	17	1
14	21	12	7	4	18 3/4	1 1/8
15	22	12	7 1/2	4	20	1 1/8
16	23 1/2	12 3/4	8	4	21 1/4	1 1/8
18	25	14 1/2	9 1/4	4	22 3/4	1 1/4
20	27 1/2	16 1/8	9 1/4	6	25	1 1/4
21	29	16 1/8	9 3/4	6	26	1 1/4
24	32	19 1/2	11 1/2	6	29 1/2	1 3/8
27	35 3/4	21 5/8	12 3/4	6	33	1 1/2
30	38 3/4	24	14	6	36	1 1/2
36	46	28 1/2	17 1/2	6	42 3/4	1 5/8
42	53	33	18 1/2	6	49 1/2	1 3/4
48	59 1/2	38	21	6	56	2
54	66 1/4	42 1/2	24	8	62 3/4	2 1/4
60	73	47	26	8	69 1/4	2 1/4
66	79	51 1/2	28	8	76	2 1/4
72	86 1/2	54 1/8	30 1/2	8	82 1/2	2 1/2
78	93 1/8	60 1/2	33 1/4	8	89	2 1/2
84	99 3/4	65 1/4	35 1/2	10	95 1/2	2 5/8
96	113 1/4	74 1/2	40 1/2	10	108 1/2	2 3/4

Courtesy Rodney Hunt Co.

SQUARE AND RECTANGULAR CAST IRON FLAP GATES



Recommended methods of installation include mounting on cast-iron wall thimble (top) or mounting on concrete wall (bottom)

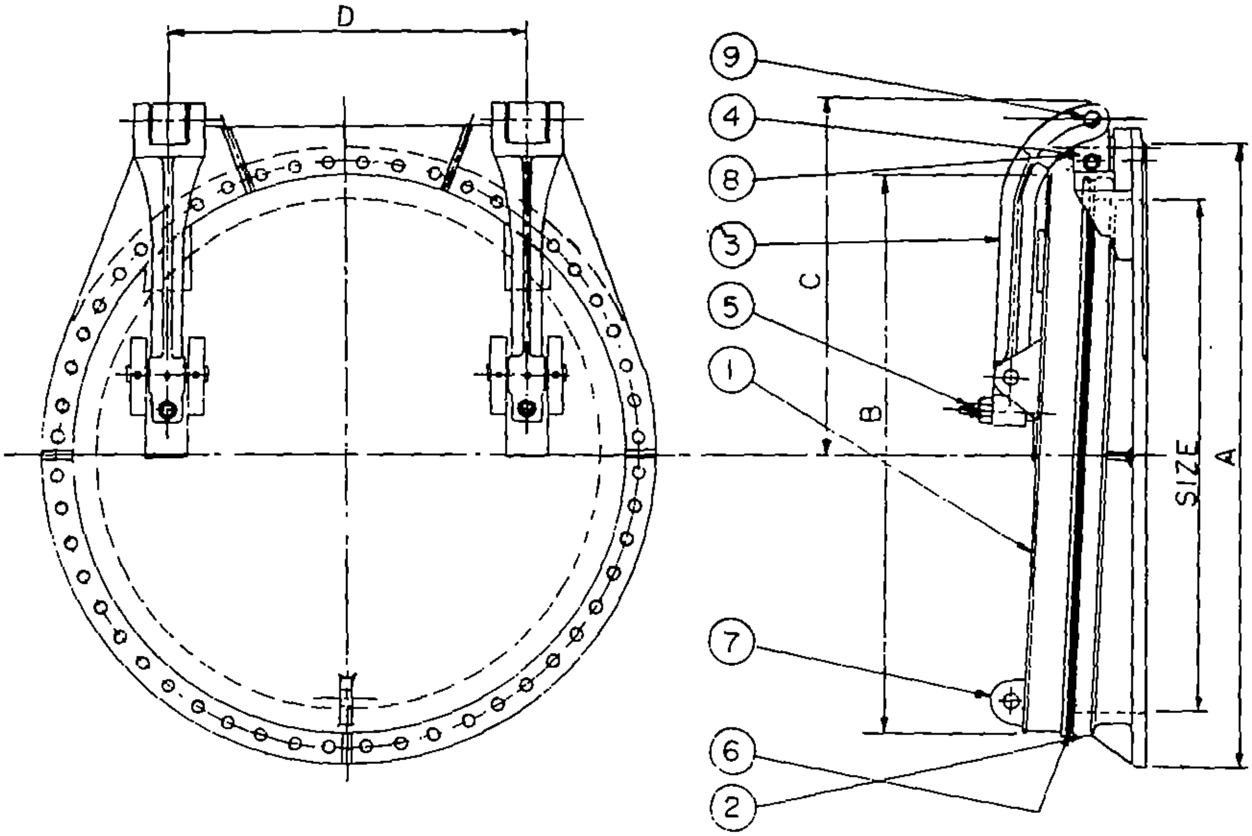


"E" thickness of mounting flange. Mounting flange drilled for mounting on a wall thimble or directly to concrete.

TABLE OF DIMENSIONS (Inches)					
Width x Height	**A**	**B**	**C**	**D**	**E**
12 x 12	19	19 1/4	9 1/2	7 3/4	1
18 x 18	25	27	12 1/2	11 3/16	1 1/4
24 x 24	32	35 1/2	16	14 5/16	1 3/8
30 x 30	38	43	19	18 1/16	1 5/8
36 x 24	45	36	16 1/2	21	1 1/2
36 x 36	45	51	22 1/2	21 1/4	1 5/8
36 x 48	45	66 3/4	28 3/4	21 1/4	2
36 x 54	46	72 1/2	32	21 1/2	2 1/4
42 x 42	51 1/2	58 3/4	25 3/4	24 1/4	1 3/4
48 x 18	56	28	13	26 5/8	1 5/8
48 x 24	56	35 1/2	16	26 13/16	1 5/8
48 x 30	56	43	19	27 1/16	1 5/8
48 x 36	56	51	22 1/2	27 1/16	1 5/8
48 x 48	57 1/2	66 3/4	28 3/4	27 1/2	2
48 x 60	57 1/2	81 3/4	34 3/4	27 1/2	2 1/4
54 x 54	64	74 1/2	32	30 1/2	2 1/4
60 x 36	69 1/2	51 1/4	22 3/4	33 1/4	1 3/4
60 x 48	69 1/2	66 3/4	28 3/4	33 1/2	2 1/4
60 x 60	69 1/2	81 3/4	34 3/4	33 1/2	2 1/4
60 x 72	69 1/2	95 1/2	41 1/2	33 1/2	2 1/4
72 x 48	81 1/2	64 3/4	28 3/4	39 1/2	2 1/2
72 x 60	83	82 1/2	35 1/2	39 1/2	2 1/4
72 x 72	83	95 1/2	41 1/2	40 1/4	2 1/2
84 x 84	95	112 1/2	47 1/2	46 1/2	2 3/4
96 x 96	107	124 1/2	53 1/2	52 1/2	2 3/4

Courtesy Rodney Hunt Co.

CIRCULAR PONTOON FLAP GATES



DIMENSIONS — INCHES

Size Diam.	A	B	C	D
48	59½	54	37¼	34
54	66¼	60	40¼	38
60	73	66	43¼	42
66	80	72	46¼	46
72	86½	78	49¼	50
78	93	84	52¼	54
84	99¾	90	55¼	60
90	104	96	58¼	64
96	113¼	102	61¼	70
102	119¾	108	64¼	74
108	126	114	67¼	77
114	132½	120	70¼	80
120	139	126	73¼	83

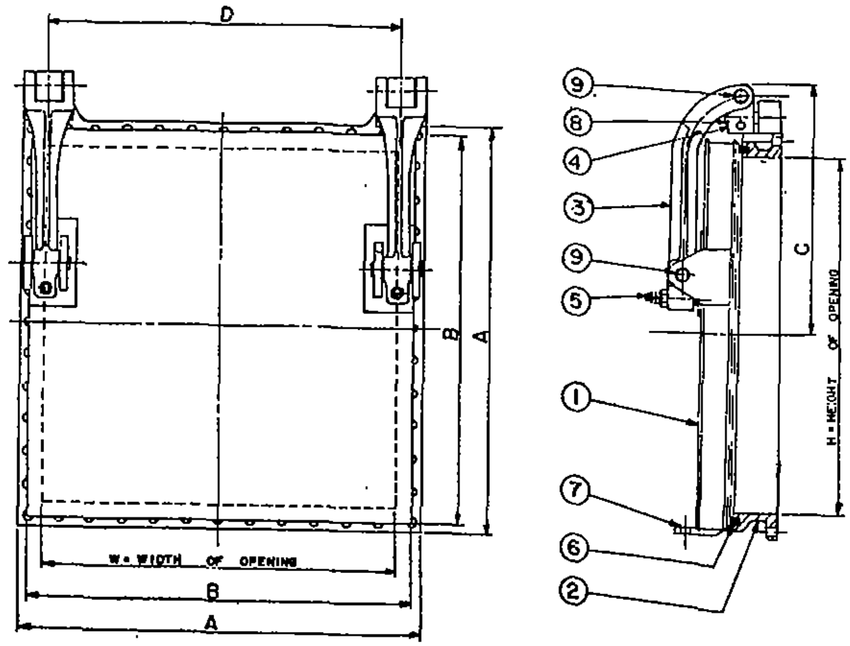
Dimensions are approximate.

1. - Flap—Stainless Steel
2. - Frame—Cast iron
3. - Hinge link—Cast steel
4. - Hinge—Bronze
5. - Adjusting screw—Bronze
6. - Seat—Neoprene
7. - Lifting eye—Stainless steel
8. - Hinge post—Bronze
9. - Pins—Bronze

Courtesy Caldwell-Wilcox Co.

FIGURE 3.1.3.4

SQUARE AND RECTANGULAR PONTOON FLAP GATES



CONSTRUCTION

1. - Flap—Stainless steel
2. - Frame—Cast iron
3. - Hinge link—Cast steel
4. - Hinge—Bronze
5. - Adjusting screw—Bronze
6. - Seat—Neoprene
7. - Lifting eye—Stainless steel
8. - Hinge post—Bronze
9. - Pins—Bronze

DIMENSIONS — INCHES

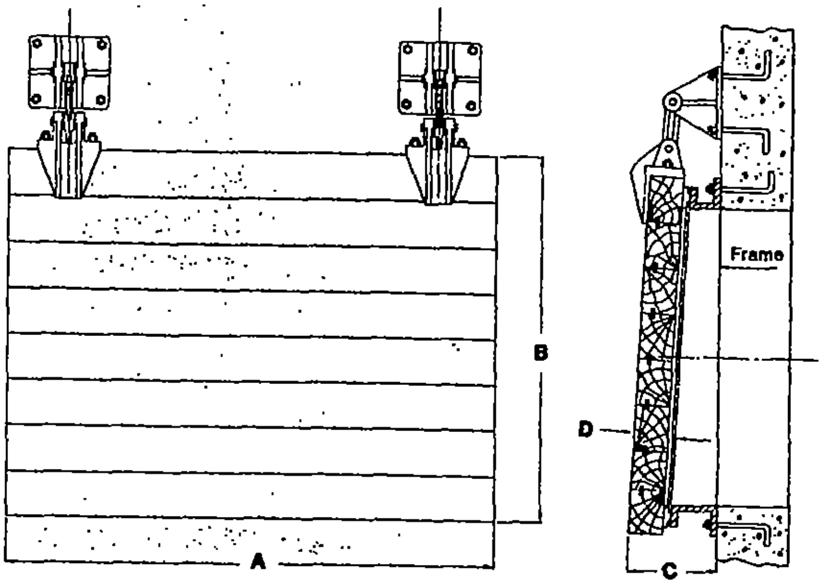
Size Wdth. x Hgt.	A	B	C	D
48 x 48	57	54	37¼	48
54 x 54	63	60	40¼	54
60 x 60	69	66	43¼	60
66 x 66	75	72	46¼	66
72 x 72	81	78	49¼	72
78 x 78	87	84	52¼	78
84 x 84	93	90	55¼	84
90 x 90	99	96	58¼	90
96 x 96	105	102	61¼	96
102 x 102	111	108	64¼	102
108 x 108	117	114	67¼	108
114 x 114	123	120	70¼	114
120 x 120	129	126	73¼	120

These gates are also available in rectangular types in any width and height in 6" increments; for example—60"x48"; 72"x96"; 108"x120", etc.
Dimensions are approximate.

Courtesy Caldwell-Wilcox Co.

FIGURE 3.1.3.5

SQUARE AND RECTANGULAR TIMBER FLAP GATES



TIMBER FLAP VALVE DIMENSIONS				
Width x Height	A	B	C	D
36x48	46	58	13	3 3/4
36x60	46	70	13 1/2	3 3/4
48x48	58	58	13 3/4	4 1/2
49x60	58	70	14 1/4	4 1/2
60x36	70	46	14	5 1/2
60x48	70	58	14 3/4	5 1/2
60x60	70	70	15 1/4	5 1/2
72x48	82	58	14 3/4	5 1/2
72x60	82	70	15 1/4	5 1/2
72x72	82	82	16	5 1/2
84x48	94	58	17 3/4	7 1/2
84x60	94	70	18 1/4	7 1/2
84x72	94	82	19	7 1/2
84x84	94	94	19 1/2	7 1/2
96x48	106	58	17 3/4	7 1/2
96x60	106	70	18 1/4	7 1/2
96x72	118	82	19	7 1/2
108x36	118	46	19	9 1/2
108x48	118	58	19 3/4	9 1/2
108x60	118	70	20 1/4	9 1/2
120x72	130	82	21	9 1/2
120x84	130	94	21 1/2	9 1/2

Courtesy Rodney Hunt Co.

ALLOWABLE WORKING STRESS (psi)

Timber		Parallel to Grain		Perpendicular to Grain
Compression	Tension	Shear	Compression	
Yellow-Pine	1550	2000	135	455
Cypress	1466	1733	133	300
Douglas Fir	1100	1450	95	390
Greenheart	3000	3300	400	1500

Greenheart (Ocotea Rodioli) is used for the lock gate sills in the Panama Canal. The greenheart is eaten by the teredo and has an average life of 9 years compared to 2 to 4 years for oak or pine. The high temperature of the water is considered responsible for its short life in Panama since there are records of its use in England and Germany for periods up to 40 years.

Generally cast iron gates are used for smaller sizes and pontoon or timber gates for the larger sizes. The use of cast iron for large flaps makes the gate difficult to handle and increases the differential head under which the gate will open. For this reason New York City limits the application of cast iron gates to 48 inches square.

The choice between timber and pontoon types depends on several factors. In New York City, where tidal waters are corrosive, the life span of pontoon gates is 10 to 12 years compared to upwards of 30 years for timber gates. The pontoon gates have a more stable shape than timber gates but eventual corrosion of the plates causes the air cells to fill with water and destroy the flap buoyance. One procedure to prevent this is to fill the cells with a plastic such as styrofoam. While timber gates have greater life they are subject to warping and destruction by marine borers.

Tide gates may be installed on concrete walls by use of anchor bolts, cast iron pipe flanges or cast iron wall thimbles embedded in the concrete wall. The use of a wall thimble is preferable.

The gate is attached to the frame by at least two hinge arms. Each arm should be provided with two pivot points with lubrication fittings. Proper maintenance requires periodic lubrication of these fittings.

The seat between the flap and frame can be either bronze or resilient material such as neoprene or Buta-N rubber. The use of a resilient material is preferable to achieve water tightness.

The gate should be provided with a lifting eye on the lower edge. It is desirable to provide a permanent chain from the lifting eye to an accessible point so that the flap can be opened when clogged, for removal of debris.

Tide gates require periodic inspection during low tides for cleaning and during high tides for observation as to their water tightness.

3.2 Design

3.2.1 Guidelines

The addition of a tide gate, a regulator and the required chambers at a sewer outfall increases the head loss through the sewer and raises the backwater effect in the sewer during periods of high stages in receiving waters. This increase of backwater levels may not be great enough to be of serious concern; however, as a precaution, the possible change in the hydraulic profile should be computed for anticipated high water levels in the receiving waters.

Since the peak storm flow and the maximum tide or stream elevation are both events of short duration, the probability of the simultaneous occurrence of the two events may not be very great and is outside the scope of this Manual. The designer must use his judgment in selecting the tide or stream high water level for use in his computations.

The additional hydraulic losses resulting from installation of the regulator and tide gate are due to: (1) Loss through the tide gate; (2) losses in the diversion chamber of the regulator; and (3) losses in the tide gate chamber. It should be noted that the friction head loss in the storm sewer downstream of the regulator may decrease due to the lessened discharge resulting from some flow diversion at the regulator.

The discharge through the tide gate will be the flow in the upstream sewer, less the flow diverted to the interceptor. If the tide gate is placed at the end of the storm sewer the flap usually will be the same size as the sewer. If the gate is placed in a chamber it usually will be square or rectangular in shape, with a width equal to the diameter of the upstream sewer, and a height somewhat greater than the water depth upstream of the gate. The gate invert will be the same elevation as the regulator diversion dam.

A typical plan of a regulator structure with a tide gate chamber and the hydraulic profile through the storm sewer and regulator is shown in Fig. 3.2.1. Sample computations for the profile shown in Fig. 3.2.1 are given in the following paragraphs.

The sample computations are based on the data used for design of cylinder-operated gates. In the latter computations the water surface in the diversion chamber was arbitrarily selected at elevation 21.00. The computations which follow indicate that the water surface should be at elevation 21.77 as a result of additional hydraulic losses due to the tide gate chamber. Therefore, in final design the computations shown herein for the cylinder-operated gate should be revised to reflect this higher water surface.

3.2.2 Design Formulas

The head loss through tide gates may be assumed to be 0.2 feet, according to some gate manufacturers. The design criterion of one city is to select a tide gate with an area 10 to 15 percent greater than the area of the combined sewer and to place the invert of the gate not more than 0.5 feet above the invert of the combined sewer. One city specifies that the head loss through the gate shall not exceed 0.5 feet; another city specifies a maximum of 0.33 feet. The relation between tide gate head losses and conduit velocities is presented in "Hydraulics Design Chart 340-1" in "Hydraulic Design Criteria" by the U.S. Army Engineers, Waterway Experiment Station, Vicksburg, Mississippi. With respect to this chart the design criteria state:

1. Flap gate head losses can be determined by the equation: $H_L = K\,V^2/2g$

where

H_L = head loss in ft. of water

K = head loss coefficient

V = conduit velocity in ft. per sec.

2. Hydraulic Design Chart 340-1 presents head loss coefficients for submerged flap gates. The data result from tests by Nagler[6] on 18-and 30-inch diameter gates.

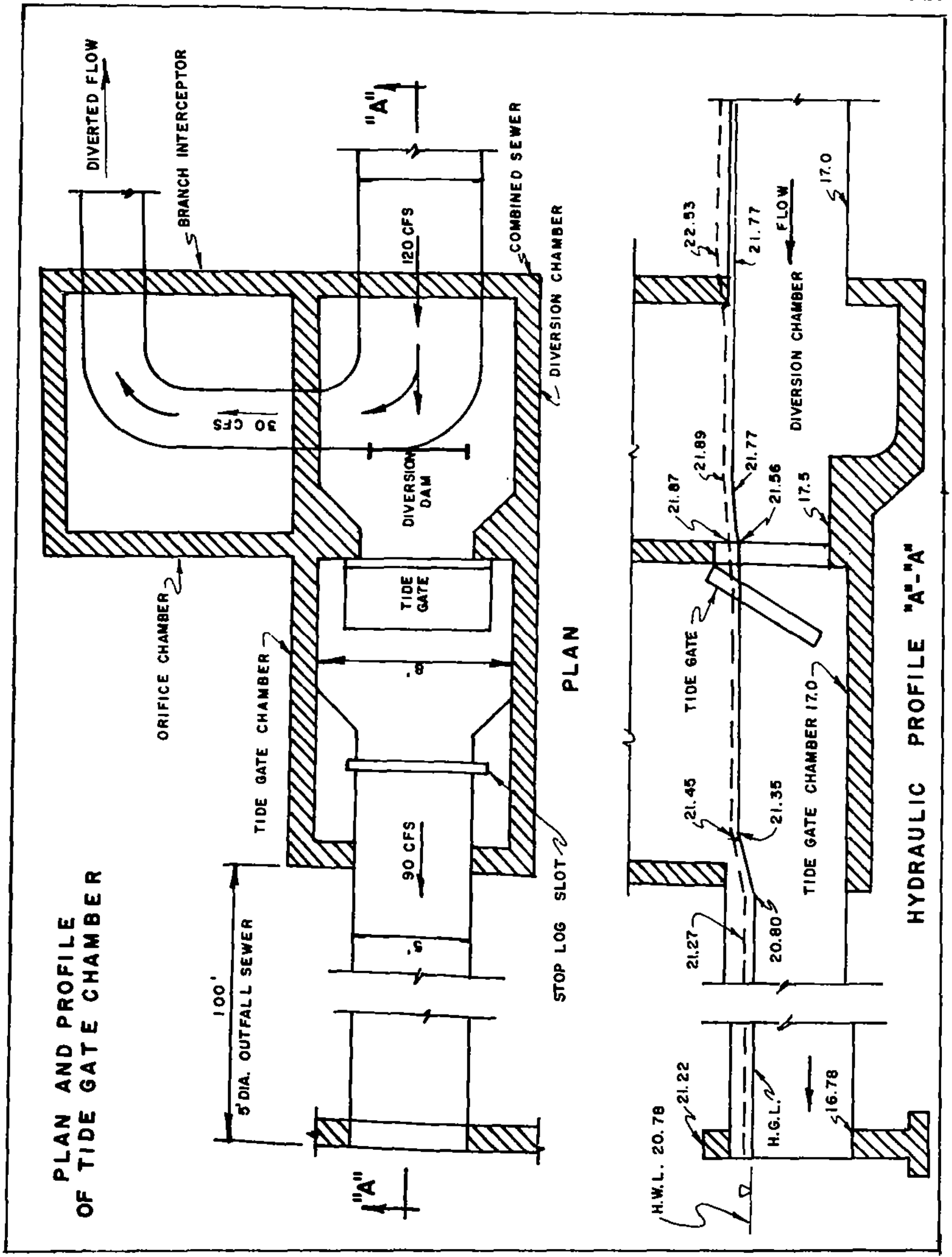
3. Modern tide gates are heavier but similar in design to those tested by Nagler. It is suggested that Chart 340-1 be used for design purposes for submerged flow conditions until additional data become available. Head loss coefficient data are not available for free discharge.

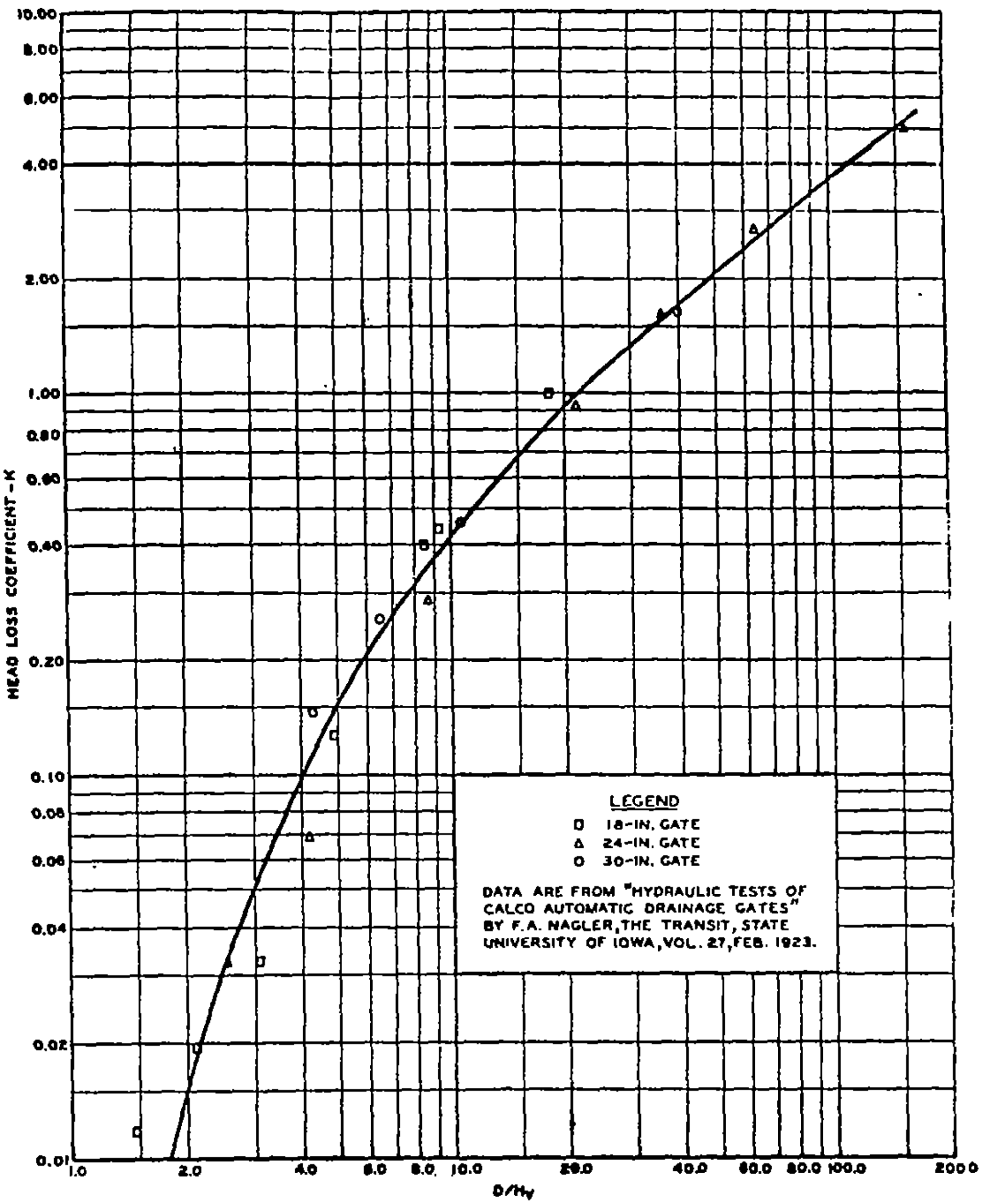
The chart in Fig.3.2.2 relates head loss through the gate to the velocity in the conduit. This chart is based on circular gates attached to circular conduits of the same size; hence the velocity in the conduit and through the gate will be similar. In the case of the regulators considered in this Manual the velocity in the upstream sewer and through the tide gate may differ; therefore, in the sample computations herein, the velocity through tide gate has been used in connection with Fig. 3.2.2.

Other hydraulic losses through the regulator are computed from the applicable formulas outlined in the subsection on cylinder-operated gates, in Section 2 of this manual of practice.

[6] F. A. Nagler, "Hydraulic tests of Calco automatic drainage gates," *The Transit*, State University of Iowa, vol. 27 (February 1923).

FIGURE 3.2.1


PLAN AND PROFILE
OF TIDE GATE CHAMBER
DIVERTED FLOW
BRANCH INTERCEPTOR
"A"
COMBINED SEWER
120 CFS
DIVERSION CHAMBER
30 CFS
DIVERSION DAM
ORIFICE CHAMBER
TIDE GATE
TIDE GATE CHAMBER
8'
PLAN
STOP LOG SLOT
90 CFS
5'
100'
5' DIA. OUTFALL SEWER
"A"
22.53
21.77
FLOW
17.0
DIVERSION CHAMBER
21.89
21.77
21.87
21.56
17.5
TIDE GATE
TIDE GATE CHAMBER 17.0
21.45
21.35
21.27
20.80
21.22
H.G.L.
16.78
H.W.L. 20.78
HYDRAULIC PROFILE "A"-"A"



EQUATIONS

$$K = \frac{H_L}{H_V} \; ; \; H_V = \frac{V^2}{2g}$$

NOTE: K = HEAD LOSS COEFFICIENT
H_L = HEAD LOSS, FT
D = CONDUIT DIAMETER, FT
V = CONDUIT VELOCITY, FT/SEC
g = ACCELERATION OF GRAVITY, FT/SEC^2

FLAP GATES
HEAD LOSS COEFFICIENTS
SUBMERGED FLOW

HYDRAULIC DESIGN CHART 340-1

WES 8-60

Courtesy Waterways Experiment Station, Corp. of Engineers

3.3 Sample Computation
Flap Gate

Note: Use same data as for cylinder-operated gate.

Assume that design high water level in receiving stream is same as normal depth in combined sewer for 10-year storm prior to construction of regulator. Determine effect of regulator on water surface in combined sewer.

V = Velocity
V_1 = upstream velocity
V_2 = downstream velocity
d = depth of flow
D = diameter
g = acceleration of gravity

	ELEVATION		
Data on combined sewer prior to construction of regulator	Invert	HGL	EL
At regulator	17.00		
D = 5.0′ s = 0.0022 Q = 120 cfs			
d = 4.0′ v (full) = 6.2 fps		21.00	
V = 7.0′ $V^2/2g = 0.76$			21.76
At outlet 100′ from regulator			
100 x 0.0022 = 0.22	16.78	20.78	21.54
∴ Design high water level is		20.78	
After construction of regulator			
Diverted Q = 30 cfs			
Q in storm sewer = 120 – 30 = 90			
Storm sewer L = 100′			
Downstream end	16.78	20.78	
d (normal) = 3.20			
d (actual) = 4.00			
∴			
compute backwater effect in storm sewer			
V = 5.4 fps $V^2/2g = 0.44$			21.22
Compute backwater curve upstream by standard-step method (see Table XVII, ASCE Manual No. 37)			
Upstream end	17.00	20.80	21.27
V = 5.5 fps $V^2/2g = 0.47$			

3.3. Flap Gate

	Invert	HGL	EL
	ELEVATION		
Flap Gate Chamber			
$V = \dfrac{90}{8 \times 4.5} = 2.5 \quad \dfrac{V^2}{2g} = 0.10$ (in chamber)			
Entrance Loss			
$0.5 \left(\dfrac{V_1^2}{2g} - \dfrac{V_2^2}{2g}\right) = 0.5\ (0.47 - 0.10) = .18$	17.00	21.35	21.45

Neglect friction loss

Flap gate loss - use Figure 3.2.2
Use 60" x 60" gate

$$V = \frac{90}{5.0 \times 4.0} = 4.5 \text{ fps}$$

$$V^2/2g = 0.31$$

$$\frac{D}{H_V} = \frac{5.0}{.31} = 16 \qquad K = 0.7$$

$$H_L = 0.7 \times 0.32 = 0.21$$

$$21.56 + 0.21 = 21.56$$

	Invert	HGL	EL
Upstream of flap gate	17.50	21.56	
21.56 + 0.31			21.87

Diversion Chamber

$$V = \frac{90}{8 \times (21.5\text{-}17.5)} = 2.8 \text{ fps}$$

$$V^2/2g = 0.12$$

	Invert	HGL	EL
Contraction loss $= 0.1 \left(\dfrac{V_2^2}{2g} - \dfrac{V_1^2}{2g}\right) = 0.1\ (0.31 - 0.12) = 0.02$	17.50	21.77	21.89
Outlet loss $= \left(\dfrac{V_1^2}{2g} - \dfrac{V_2^2}{2g}\right)$	17.50	21.77	21.89
$= 0.76 - 0.12 = 0.64$			
Combined sewer	17.00	21.77	22.53

Therefore the installation of the regulator will raise the water surface of the combined sewer upstream of the regulator during a 10-year frequency storm by 21.77 – 21.00 or 0.77 feet.

SECTION 4

INSTRUMENTATION AND CONTROL OF REGULATOR FACILITIES

CONTENTS

4.1. Elements of Instrumentation

Activation: General

This section is directed principally at the more recent techniques of control and instrumentation that may be adaptable to the development of more suitable means of regulation. It is prepared from the viewpoint of the electrical and instrumentation designer: the subject matter pertains specifically to equipment for:

1. Metering - means of measuring and sensing system conditions;
2. Telemetering - means of transmitting data to some data gathering points;
3. Communications - means of interconnection from remote to data gathering point;
4. Data Handling - means of collection, display, storage and manipulation of data;
5. Decision Making - means of translation of data to control requirement;
6. Supervisory Control - means of dispatching control to activation facilities; and
7. Activation of Control Element - means of activating regulating device.

These concepts imply the establishment of a total system control center at which point a complete system of sewers and all its associated components appurtenances may be under the direct supervision and control of management. This will be a necessity at some large jurisdictions and to a lesser degree at smaller jurisdictional systems where only a few manually supervised elements are used. The general principles will be the same and installation in the instrumentation-control field should embody the concept of the ever-widening scope of which each element may become a part.

The development of the regulation control center must be a step-by-step undertaking, starting with the gathering of data and implementing remote control while gradually increasing the control center's data handling capability with additional equipment.

Present regulator practice makes use of both fixed and adjustable hydraulic devices such as: Dams, horizontal orifices, vertical orifices, overflow weirs, leaping weirs, adjustable gates, tipping gates, and siphons.

The amount of flow in each case is seldom measured, but by nature of the regulator design is supposed to be within certain limits based upon hydraulic calculations under assumed conditions such as, for example, free discharge downstream. Two major conditions arise, however, which make the effectiveness of present regulation practices a continuing problem. First, the desired orifice becomes altered or gates malfunction because of clogging and second, downstream channels may become surcharged. Since there is usually no means of indicating flow, there is no means of indicating the degree of regulation which occurs.

In the case of fixed or static regulator stations, nothing can be done to correct a control malfunction except to remove the obstruction. Sensing of the problem can be accomplished and communicated with suitable identification to supervisory personnel and conveyed to maintenance personnel for remedial action.

Adjustable regulating stations can be monitored, and gate openings can be remotely adjusted from a central control, provided such facilities are made available, to compensate for the changed conditions affecting the station. If, for example, a partial blockage restricted an orifice, the gate could be opened wide to effectively change the port area to allow the desired flow.

With regard to instrumentation and activation facilities, instrumentation only applies to static regulators. In this respect, monitoring devices with suitable communication facilities can detect and indicate the hydraulic conditions either in the vicinity of the regulator or at some point on the system that reflects the operating condition at the regulating station.

Both instrumenation and activation facilities can be used with automatic dynamic regulators. In this application instruments can be used for sensing the conditions and for handling information, whereas the activation facilities may be employed to manipulate the configuration of the regulating stations.

The concept of controlling an individual regulating station is a simplification of the concept of regulation as it applies to a complete waste water system. Complete system regulation requires the development of facilities and techniques to efficiently route, limit divert, transfer, and "park" or store waste waters.

Regulation of sewers, like any other control system, can be broken down into the following elements: Measurement; status determination; information or data gathering; manipulation of data; decision making; execution, verification, and evaluation.

Measurement and status determination is effected by sensors of various types developing electrical signals to represent such objectives as flow, level, head, differential pressures, gate positions, and equipment status. Data gathering equipment is used to condition or code electrical signals for transmission over usual communications channels. Equipment for manipulation of data consists of indicators, recorders, loggers, alarms, and computers. Decision making is performed by supervisory personnel or by computer programs. Execution is by dispatching service and maintenance personnel, or by employment of supervisory control equipment for remotely operating the stations. Verification is carried out by updated measurements and status indications. Evaluation is a decision or judgment-making process, either manual or automatic, to determine the results of the initial execution of a control action. Repeated control cycles are performed until satisfaction occurs.

The control equipment may take many forms. Generally, sluice gates or shear gates will be employed to limit and re-route flows; whereas pumping equipment may be used for transfer to and from off-system storage or holding facilities. Pumps also may be used for transfer within a system to take full advantage of system capacities for storage. Not only is it essential to manage storm water flows, but also some treatment, chlorination for instance, may be required. In such instances, the control equipment will likely include remote dosage monitoring of chlorinators with the rate of chlorine feed automatically paced by the measured rate of storm water flow. Additional sensors may be required for determination of such situations as chlorine residual and contact time before release from the system.

Usually, means to transfer flow has a variable capacity in order to match the incoming flow. Equipment used may include control and monitoring facilities for variable speed pumping equipment.

An interesting example of regulated pumping is the case where pumping from the downstream terminal of an interceptor sewer is performed only at a rate of flow necessary to lower the hydraulic gradient so that incoming flow to the interceptor can be accepted, thus always pumping at the minimum head necessary to match the incoming flow. Under this condition the pump station wet well is at minimum level at maximum flow or maximum level at low flow or low pumping rates. Moreover, the capacity of the interceptor is used to its maximum capability for storage. Such a scheme becomes quite complex and requires programmed control which may either be built into the control equipment or be effected by computer.

Although the treatment of sewage falls outside the scope of regulation, those who manage the regulation of a complete system must be concerned with the operating capacities of plants and with outfall sewer conditions. Thus, plant flows and receiving body water levels are pertinent data required at the regulator control center. Additional stream monitoring data pertaining to water quality also might be transmitted to the control center for overall guidance and record purposes. Additional data such as weather reports from the Weather Bureau and rain gauge data telemetered to the control center should assist management to effect adequate controls when a storm impends.

Successful development of means to effectively regulate complex sewerage systems, either combined sanitary and storm wastes or separated wastes, requires a management information and control system. In spite of the interest that exists, as is evident from the number of articles and discussions on the subject, few such information systems actually have been implemented. One reason for this has been cost. Another reason is that there is neither a well-defined perception of the range and extent of the information and control requirements nor tried and proved methodology for its implementation. The traditional justification for information systems, monitoring of sewer levels for example, has been based to a great extent only on reduction of operating costs. Justification for an information system, in the future, should be based on the net worth of the information. The net worth may be defined as the difference between the value of the information obtained and the cost of obtaining this information. Traditionally, the instrument and control designers determine the cost; Management must determine its value.

Information is even more valuable when it flows to and from management, allowing decision-making and execution, and thus more responsive control. From an instrument and control standpoint, a sewer monitoring system is an example of information flowing only one way—to management. By implementing supervisory control equipment for remote control, the value of the information is greatly increased if it allows management to exercise real time control. Real time control is the ability of management to detect and correct a deviation from plan or standard before the deviation becomes so great that it is not possible to return to the original plan or standard. It is not necessarily instantaneous or even fast control, since the speed of response required for a real time control depends upon the nature of the activity being controlled. For waste water systems control the speed of response usually may be in minutes and hours.

The constraining factors in the development of information and control systems are control facilities, communications, power, and site preparation. None of these except hardware is necessarily difficult and needs no particular discussion in this manual. Very little has been accomplished, however, in the design and development of suitable hardware for sensing the rate of flow. In this respect, and at the present stage in the art of instrumentation, it should be recognized that immediate values of velocities and levels are of more value than totalized quantities of waste water.

Determining the specific information and control requirements is probably the most critical part in the design of any information and control system. These needs also must be taken into account in the future design of sewer systems. The cost to harness a regulating station with monitoring devices and remote control has little relationship to the size of the station. In future designs it may be prudent to employ only a few large regulating stations rather than a large number of smaller ones. It will also be important to locate regulators where they can be conveniently attended and serviced.

Information and control systems offer tremendous benefits to the water pollution control agencies and represent practically a new frontier for instrumentation and data handling. Examples of beneficial regulating practices are many.

In one jurisdiction where storm water overflow or diversion occurs the major purpose is to avoid hydraulic overload of treatment works in addition to avoiding flooding of local areas. Overflow chambers are metered and other overflows are electrically controlled and telemetered to the plants for their operation. The control center is located in a main office building to which data are transmitted concerning rainfall incidence and waterway elevations. The engineer of waterway control provides information to the engineers of treatment plant operation who decide the course of action.

To achieve the objective of using available storage within the existing combined sewers for regulating storm water flows, the jurisdiction installed a "Computer Augmented Treatment and Disposal System." Reduction of sewage overflow frequency and magnitude also is part of its objective. When overflows cannot be avoided, the system controls discharges at selected stations to minimize harmful effects on marine life or public beaches. Storage control is effected through remote electric control and local automatic controls of the pneumatic type. These local control units come into use only when the remote control equipment fails. Gates at each outfall are remotely controlled by electronic circuitry. Remote control of the datum level chosen at each location is carried out by transmission of an operation command signal to the remote terminal equipment. When the desired datum has been reached, a command signal is transmitted to the remote terminal to deactivate the equipment. When the remote control units fail, local automatic control is restored. The control center is outfitted with an operator's console and wall map which relate to the system. Data are telemetered to a central location over leased telephone lines and the information is entered in a process control computer which also directs data gathering.

At another jurisdiction, it has been found that about 80 percent of the annual overflow volume is discharged from 20 overflow structures. Consideration is being given to the elimination of all overflows in some areas. This would be accomplished by bringing all combined sewers to a central gate chamber where the gates would be power-operated and remotely controlled by means of a telemetering and supervisory control system. The chamber would be operated as a single overflow during periods of wet weather. Control of the overflow would be accomplished by a central operator who would have telemetered data concerning waste water flows at treatment facilities, the water level and available storage capacity in the intercepting sewers and the water level at critical points in the system and at the gate chambers. Thus the operator at the control center could affect the flow throughout the system. Use would be made of the monitoring and telemetering system in the operation and control of the system, in particular for surveillance of the pump stations for malfunctions, failures, and other system problems.

The benefits of flow control in combined sewers at one sanitary district appear to warrant a significant expenditure for equipment. Flow in the sewer system was studied, using pneumatic depth of flow recorders placed at key positions. Purpose of the gauging was to determine the extent of system loading, in addition to gathering other data. In 1960 it was found that a volume equal to 10 mgd in the joint interceptor sewer required an expenditure of $600,000 based on dry-weather flow. This means that every 10 mgd of storm water removed from the joint interceptor had an equivalent worth of $600,000 of sewer capacity. This concept of providing capacity for sanitary flows led to consideration of using powered regulators and a system of controls for removing flow from, or permitting flow to remain within the interceptor system. Effective control of the regulators was seen as a measure for reducing the overall quantity of raw sewage diverted to receiving waters during rainfall periods. The system being considered included an integrated system of regulator operations with supervisory control of key regulators. The regulator operation would be based upon interceptor usage. Power-operated gates controlled by a supervisory system from a control center would use telemetering to provide information concerning the gate positions, flows, and flow levels in the interceptor sewers. Data collected would inform the operator of the system the situation and permit system adjustments. The operator would have the choice of bypassing flow quantities at certain locations. Evaluation of the receiving water conditions at various locations would be made by the operator who would make required adjustments. Automatic readout of data for analysis and use of manual or computer techniques are visualized.

Still another example of the requirements of monitoring and supervisory control is the situation in another sewer district where a second conduit will be installed to parallel an existing relief sewer. In this case, it will be necessary to retain peak flows in one of the two conduits until a quantity is reached where it is possible to divide the flow between the two sewers and still maintain adequate velocities in both. Obviously, some form of level and velocity monitoring and power-operated gates are likely solutions.

4.2 Metering

Regulation, herein is defined as the control of waste water flow. Control implies exercising direction over the amount, the rate of flow, and the routing of the flow. Effective regulation therefore must be accompanied by some means of measurement.

Important characteristics of waste water flow are: (1) Conduits usually are only partially filled; (2) substantial amounts of debris are carried; (3) flow is not under pressure other than gravity; and (4) conduits frequently are located at considerable depths below grade.

Conventional measuring devices used on water distribution systems are not practical for measuring waste water flow. Open channel flow metering structures can be employed with some degree of success but they are accompanied by additional problems peculiar to the waste water system. Such structures can become very large and expensive and are most appropriately placed near the surface where they are more accessible. Open channel meters are not only directional, but also become inoperative whenever they become submerged.

Always a problem of using an open channel metering structure is the measurement of water level. Most of the open channel flowmeters are designed with the intent of using floats for measuring levels. The use of floats in waste water metering practices only can be practical for temporary meters or those which will be installed within stilling wells and continuously purged with clear water, or those which can be continually supervised and maintained. The use of bubbler systems for measurement of differential levels across Parshall flumes has been employed with greater success. Bubbler systems for direct level measurements provide some advantages over floats.

None of the conventional flow measuring devices is designed for the express purpose of waste water measurement and all presently in use are designed for a much narrower range and higher accuracy than would be required for the monitoring of waste water flow. Therefore, the practice of regulation can not be expected to be any more successful than the available means for sensing flow.

Successful regulation practices will depend on the development of new methods, principles, and designs of flow measuring devices adaptable specifically to sewers and waste water characteristics and environments. Unfortunately, the present state of the art of waste water flow metering is seriously behind most other metering accomplishments.

Managers of sewer systems must make known these requirements to research, development, and manufacturing organizations. Rather than concentrating on the development of flowmeters, for example, it might be wise to explore the development of a pair of sensors, one to determine level and the other velocity. Then with level and velocity as basic data, the flow could be computed by taking into account the conduit configuration. Immediate velocity and level measurements would provide management with a better description of the conditions taking place at some point in a conduit than would a flow measurement, and each possibly could be more accurate than some emperical determination reflecting the combination of the two.

Another concept that might be explored is that of sampling for level and velocity measurements. Such an approach might lend itself to the possibility of employing retractable devices or probes for these purposes so that fixed obstructions would not impede the normal transport of solids and debris. Retractable probes could continually sense level and velocity, interrupted occasionally for retraction, so that any debris held by the probes could float on downstream. The probe could not only be level and velocity sensitive, but could also be bi-directional, sensing velocity in either direction. Such a probe should be sufficiently strong to withstand the impact of heavy floatables and be constructed of corrosion-resistant materials. Probes of this type are patented and are presently being considered for development by several instrument suppliers. It may be wise to ease the requirements for accuracy and sensitivity normally expected for metering and settle for greater durability and simplicity of equipment.

Other new developments in the field of measuring liquid velocity and volume flow rates make use of sonar principles to determine transient travel of an acoustic pulse between submerged probes. The meter probe provides an unobstructed flow path without head loss. This equipment is represented to measure flows from 0.02 ft./sec. to 300 ft./sec. continuously and to have successfully measured flow in a 24-foot-diameter conduit at no more than one percent error.

A relatively new device which is convenient for use in measuring liquid level is the controlled leak,–a precision, porous-metal gas flow restricter. This device can be used to bleed gas such as nitrogen from a bottle, at a rate of less than one bubble per second. The back pressure on a pipe bleeding the gas into a fluid bears a direct relationship to the length of the submerged portion of pipe. For measuring liquid level, this allows the use of a nitrogen bottle and controlled leak to replace the usual installation of an air compressor and differential regulator and the accompanying appurtenances normally required for a bubbler system. Such a system can last for many months without refilling a standard size gas bottle.

Solid state pressure, level, and flow transmitters are being developed for telemetering which can be powered over a standard telephone line, thus eliminating the requirement for power at the transmitter site.

4.3 Telemetering

4.3.1 General

Telemetering is a means of Conversion of a measured variable or sensed condition into a representative electrical signal, the transmission of that signal, and its reconversion to a suitable quantitative form which may be displayed, indicated, recorded, logged, or stored and utilized to compute or control.

The selection of the type of telemetering equipment to insure its maximum effectiveness for a particular application requires not only a careful evaluation of the many types available, but more significantly of the design criteria which may be imposed by the particular purpose for which it is applied.

For regulation practices, certain design criteria are dictated by the characteristics of a sewer system. Such design criteria are:

1. Wide coverage–data are required from all over the system and its environs;
2. Relatively small amounts of data–only a comparatively few and in some cases only one point of data is required from each site;
3. Unattended sites–data measurement are frequently required at unattended sites;
4. Uncontrolled environment–data measurement are generally at site of uncontrolled environment; and
5. Alterable and expandable–points of data requirement occur gradually and in small increments, only to keep pace with sewerage system expansions.

From the above, it readily can be determined that certain features of the outlying station telemetering equipment are particularly desirable, such as:

1. Inexpensive;
2. Infrequent service requirement–not more than quarterly or semi-annually;
3. Applicability for wet and corrosive environment;
4. Applicability for unregulated, normal power supply;
5. Applicability for ordinary two-wire telephone;
6. No distance limitations; and
7. Adaptability to grouping of a number of data signals on one communications channel.

Of the many major types of telemetering equipment available, some of the most commonly employed with respect to their transmitted signals are as follows:

4.3.2 Current Type

The output signal is a variable electric current. This type requires a continuous two-wire, fully-metallic individual circuit and is quite limited in distance. It is most suitable for in-plant and on-site telemetering, particularly where electronic instrumentation is involved.

4.3.3 Voltage Type

The output signal is a variable voltage. This type requires a continuous, two-wire fully metallic individual circuit, is limited in distance, and is quite subject to induced interference. In many instances this type requires a shielded circuit.

4.3.4 Frequency Type

The output signal is a variable frequency. This type requires two-wire circuit or the equivalent. It has no distance limitations and is suitable for high speed data transmission. It has not experienced widespread use. for water or waste water signaling, perhaps because it generally has been more expensive and more of a proprietary item than other types available.

4.3.5 Pulse Count Type

The output signal is a variable rate of operation of a contact-making device. This type is a simple, inexpensive electro-mechanical system. It requires only a two-wire circuit or the equivalent and has no distance limitations. Primarily, it is used for dynamic variables such as flow or running counters, and generally is not adapted to more static variables such as pressure, level, or position.

4.3.6 Pulse Duration

The output signal is a variable duration of the closure period of a contract-making device being operated at a constant rate. This type is frequently called time-impulse. Usually it is a simple, inexpensive, electro-mechanical system, utilizing any two-wire circuit or the equivalent. It has no distance limitations and commonly has been used for water and waste water signaling of such variables as flows, pressures, levels, and positions.

4.3.7 Digital

The output signal is a coded pulse train. This type of equipment generally is more sophisticated and expensive; however, its signal format is particularly suitable for automatic data logging and data handling. It has very high accuracy and speed transmission, operating over a two-wire circuit or the equivalent without distance limitations. It is the newest in the art of telemetering; although not yet developed to the stage where transmitters specifically designed for waste water measurements are yet available.

4.3.8 Commentary Concerning Telemetering Equipment

In addition to taking into consideration the characteristics of an overall system, the desired features of the particular application, and the most appropriate transmission signal, it generally has been necessary to choose and specify equipment for which there are competitive suppliers. Since pulse duration type of telemetering is furnished by a number of manufacturers and also meets the normal requirements, it is perhaps the best known and most widely used system for control of combined sewer flows. Presently, governmental jurisdictions successfully utilize a large number of pulse duration type telemeters. In such cases it might not be prudent to change unless there is sufficient justification. Advantages of the other types, however, should not be overlooked.

Presently, telemetering consists of remote transmitters and indicating or recording receivers located at pumping stations and treatment plants, or central operations control centers. No automatic data handling other than the pointer or pen positioning on the receiver is usually involved. If additional handling of the data is required, however, other considerations are necessary. For example, a time-impulse signal cannot be adapted for automatic logging. So the various types of telemetering devices should be reviewed with the prospect of automatic data logging in mind.

Automatic data logging and computer data handling require that the data signal be in digital form. It would seem that digital telemetering would be a more suitable choice of equipment. Unfortunately, at this time no primary metering equipment for waste water type measurements has a direct coded digital output. To obtain a digital output signal, it is necessary to employ a conventional primary meter with a current or voltage output, (an electrical analog output), then to use an analog-to-digital converter to obtain a digital output for transmission to the control center. Such a scheme requires expensive and elaborate facilities at outlying stations. This is contrary to the design criteria, and rules out the use of digital telemetering as a suitable means for wide area gathering of flow, level, pressure, and position data. This is not to say that its use will not be common when more practical digital transmitters are developed. Nor should this be interpreted to apply in other circumstances where a block of digital information is available at a site with suitable environment for transmission to another suitable location. It could be concluded that digital telemetering at least, would not be considered as a substitute or replacement for the time-impulse type.

Frequency-type telemetering is suitable as a substitute for pulse duration telemetering. However, because it is not available from as many sources as the pulse duration types, there is no particular price advantage, and because many jurisdictions have a large amount of pulse duration equipment in service, a case for its specific use would not seem arguable.

Pulse-count-type telemetering, from an electrical standpoint, also is suitable from the standpoint of design criteria. Its application is generally limited, however, to displacement flowmeters or counting systems which require a rotating body in the stream;

hence it is not suitable for waste water applications. Moreover, it is not as readily adaptable to time division or tone-type multiplexing which are simply techniques for grouping a number of transmitted signals on one communications circuit. Usually where a number of analog data functions are involved, the pulse count code would be converted to one of the other forms of telemetering for multiplexing.

Voltage-type telemetering only should be considered for on-site applications because of its distance limitations. It does have the advantage of having the data measurement in an electrical analog form which lends itself to direct analog-to-digital conversion.

Current-type telemetering should be considered only for on-site applications because of its distance limitations. It has the advantage of having a data signal of an electrical analog form suitable for direct analog-to-digital conversion. Furthermore, it is not so susceptible to electrical interference and usually would not require a shielded cable for its transmission circuit. Consideration should be given to the use of current-type telemetering for on-site applications. Not only is it adaptable to digital data, it has immunity to interference. The inherent requirement of only a simple ammeter for an indicating instrument make it desirable for compact panel arrangement. The present trend in electric or electronic instrumentation is toward the current and voltage types. The current type is most frequently used. Wherever the measurement data are required in digital form, it is first necessary to obtain it in either its current or voltage analog. For the accumulation and conversion of much data to digital form at any on location, current-type metering is quite appropriate.

Pulse duration telemetering holds a somewhat unique position for water and waste water measurement. Certainly none of the digital equipment presently available can supplant its existing utilization in water and waste water facilities. Most types of chemical feeders as standard equipment are presently designed to take pulse duration signals. Many pump controllers and most analog instrumentation are designed for use with pulse duration equipment. Not until the requirement for data in a digital form arises is the use of pulse duration telemetering seriously questioned.

Perhaps the most straight-forward means for converting pulse duration to digital form is the employment of a standard re-transmitting slide-wire-type potentiometer in a pulse duration receiver. Voltage or current in the potentiometer circuit could then be converted to a digital signal proportional to the position of the slide-wire. The use of a slide-wire, however, introduces another component requiring service and replacement. Therefore, it is desirable to obtain a current or voltage signal conversion from pulse duration without the requirement of a slide-wire.

Another possibility of converting the pulse duration signal to digital form is the employment of a shaft position to digital encoder in a pulse duration receiver. Although this is not available with present standard receiving equipment the possibilities of this concept should be more thoroughly investigated before commitment is made to acquire digital conversion equipment.

4.4 Communications

4.4.1 Communications Facilities

The most common communication link for telemetering and supervisory control in the waste water field is the leased telephone line. The monitoring of regulation practices, like that of monitoring in most other related industries, has used leased telephone lines for both their existing telemetering circuits and their supervisory control circuits. Generally, most experiences with the leased lines have been reasonably successful, particularly in cases where the importance of the communications link has been sufficiently impressed upon the telephone utility. Another means of communications which could be employed would be by microwave.

4.4.2 Microwave Facilities

Microwave, a form of directional–point-to-point–communications utilizing ultra high frequency equipment, provides a very large communications signal capacity. Usually, there is not a sufficient quantity of data signals at any given station on a waste system to justify the choice of microwave on that basis alone. Generally it is justified on point-to-point applications where the distances are quite great, and it is found that leased telephone service either is not available or that the service simply is unsatisfactory. Microwave equipment must be operated on a line-of-sight basis from transmitter to receiver, with intermediate repeater stations as required by the nature of the terrain. Generally, microwave is too expensive for the wide coverage necessary for control and supervision of the many remote stations which may make up a waste water system.

In cases where it is necessary to lease communications links from several intermediate telephone companies to form a complete circuit, it may be necessary to employ microwave equipment.

Microwave equipment is available from a number of suppliers, is reliable and flexible, but requires maintenance by an organizations's own personnel or by the service contract.

4.4.3 Telephone Lines

Leased telephone lines, as normally furnished by a telephone company, fall into three principal classifications. Other classifications have been recently established for very high speed data transmission. These classifications may vary in quality and performance from one place to another and between companies.

1. Class 1, or Class C—is a direct current slow speed telegraph circuit. Pulsing speeds are limited to 15 cycles per second. These circuits are generally continuous metallic with ground return. Such circuits are quite suitable for single pulse duration telemetering or individual control circuits and presently are used under appropriate conditions by many municipalities.
2. Class 2, or Class B—is also a direct current (DC) or low frequency (AC) teletypewriter or teleprinter circuit. Pulsing speeds are limited to a range generally of 60 to 100 pulses or cycles per second. Frequently, the Class 1 and Class 2 circuits are not available in residential areas. No particular need for this class of circuit is foreseen.
3. Class 3, or Class A—is a voice grade circuit. Generally, this class circuit may pass audio frequency (AC) signals up to 3000 cycles per second on short distance lines. Longer lines using repeaters usually pass audio tones from 300 to 3000 cycles per second. This type of line is most suitable for normal requirements in the subject field.
4. Although not normally required, other special classes used for high speed data transmission have been developed and can be furnished under special arrangements. Prior to consideration being given to the actual acquiring of any high capacity, high speed data handling equipment, the telephone company should be contacted regarding the type of equipment, the nature and characteristics of their communications circuits, availability, and cost.

4.5. Data Handling

4.5.1 General

Data is information that can be expressed symbolically—measurements, time, equipment status, identification, etc. Indicating and recording instruments, alarms, mimic busses, and lights all have been used for data handling. Data use will become more complicated as it is used with regulation control practices and techniques. At some point, automatic handling of data will become necessary. The system designer then must consider the use of computers for logging and control.

Data logging has generally been the first step toward data handling beyond the usual display of data on indicator scales or recorder charts, or lamp indications. The first models of data loggers usually used some means of receiver self-balancing potentiometer to position a shaft upon which a shaft position encoder was mounted to digitize the output of the receiver. Various inputs were switched to the receiver encoder combination by telephone-type stepping switches. The output of the encoder was then fed to an electric typewriter. With the exception of the encoder, the components—receivers, stepping switches, and electric typewriters—generally had been in use. Applications of such equipment have proved quite successful in logging a great amount of data in a short period of time, and where there was adequate time between uses for service and maintenance. Utilities requiring trouble free, day-in, day-out logging service, however, found such equipment to be in frequent need of service and repair. These electro-mechanical-type data loggers are not recommended for the continuous service required for waste water regulating practices.

A second generation of data loggers has been developed, using solid state voltage or current generators in place of the self-balancing potentiometers, digital voltmeters to digitize in place of shaft position encoders, and reed or mercury relay type scanning programmers in place of stepping switches. Such instruments greatly reduced some of the problems encountered with the earlier loggers and permit higher speed and more flexibility in setting alarm points or set-point control.

Either first or second generation loggers are basically prewired systems. The second is easier to modify because of its use of pin boards for convenient changing of alarm, span, and zero suppression settings. In either case the output of the logger is basically a fixed log only, with no convenient means of data manipulation such as might be required if the data are to be used in conjunction with a computer for trend alarms, computational analysis, averaging, or other programmed requirements.

The most recent data logger is the general purpose, stored-program digital computer which is used as the central data processer of a modern data handling system. Once the digital computer is put into the system, it will do the jobs which were difficult or impossible to do with the original logger. It will also do anything the second generation loggers could do, and store data, permitting the data to be used in whatever manner a programmer may call for, including closed loop computer control.

4.5.2 Digital Computer Capacity

The data handling digital computer can have the following capabilities:

1. Computer memory can store alarm settings, and zero and suppression settings, thus eliminating fixed wire pin boards or separate instrument alarm contacts.
2. Subroutine programs can eliminate the clock and calender required in the earlier type loggers.
3. Computer can remember alarm points during the last scan and initiate and display programmed instructions when an alarm is found.
4. Linearizing of signals can be done by computer programming.
5. Pulse inputs can be counted directly by the computer, eliminating the individual pulse counters.
6. Time duration inputs can be read directly by the computer by means of program interruptions.
7. Analog-to-digital converters can become a part of the computer.
8. The computer can measure zero drift on low level signals and compensate for it.
9. The computer can sense an excessive rate of change of variable, to give trend alarms prior to reaching the point of alarm condition.
10. Simple to complex computations can be performed on the data received.
11. Memory of the computer permits an operator to recall data prior to an alarm for examination. For example, in the event of an alarm, the data handling system can automatically or on demand print out the values of significant variables for say every ten seconds of the five minutes preceding and following the time of alarm.
12. A trend recorder can plot data from storage. For example, in only a few seconds a 24-hour recording of an input such as a flow, pressure, or temperature can be made by simply selecting the variable to be analyzed.
13. The computer can accept new commands from the operator.
14. The complete logging program may be revised or modified without making any external changes.
15. The digital computer-type data handling system can be adapted to closed loop computer control.

The greatest advantage of the digital computer logger is that once it is put into the system, it can be programmed to do additional work unforseen at the time of its original installation, at almost no additional cost.

The data handling facilities must have the capacity for handling a vast amount of data, yet be capable of discriminating between that which is normal and that which must be called to an operator's attention. Data requirements for the future can not be determined with accuracy. Thus a hard-wired electro-mechanical logging system should not be purchased. Hard-wired systems become more and more complex and inflexible as the number of points of data increase. The computer-type logger, on the other hand, can originally be purchased with a great amount of data handling capability with characteristics and execution methods to be changed as the input data amount increases.

Concentration of effort on the acquisition and accumulation of suitable data must precede installation of a system.

4.6. Decision Making

When measuring devices, telemetering, communications, data handling, supervisory control and outlying station activation facilities have been acquired, only the decision and execution need be performed to close the regulating control loop. How well the system is regulated then becomes a matter of interpreting the data and judging the amount of control to be executed. Deciding what to do may be an extremely flexible arrangement wherein the operations control center operator or attendant uses his best judgment: Or it may be a fixed and inflexible arrangement determined ahead of time and incorporated in a programmed operation automatically performed by the data handling equipment or computer. Arguments can be made for both arrangements.

A capable attendant can permit a wide range of allowable conditions under various circumstances, not necessarily defined by only the measured inputs; whereas, with the computer, more nearly identical controlled conditions can be depended upon during similar situations.

Closing the control loop manually is known as off-line control. Closing the control loop automatically is known as on-line and real-time control.

A system which includes data logging, data handling and supervisory control equipment of the recent and more sophisticated types, can, with slight modification function with some on-line control. Any system with the capabilities of on-line control must be capable of switching to off-line control when desired.

4.7 Supervisory Control

4.7.1 General

For management to exercise fullest authority over the regulating control facilities, it is desirable to have information regarding the effectiveness of a regulator, and means to override or put into effect additional controls. Control is a result of some decision-making process and may be performed manually or automatically.

Supervisory control equipment consists of three basic elements: (1) The dispatcher's equipment; (2) the means of communication; and (3) outlying station equipment. Systems will vary from the simplest—a control switch, directly connected to a regulating gate operator—to a sophisticated regulating system operated by a computer on closed loop control. The methods and techniques used to transmit information are similar to those used for remote control. A computer handles not only data, but also generates control output, either manually or automatically initiated. It is necessary to recognize the essential differences between conventional supervisory and computer control. Because supervisory control and computer control are such broad, generic terms these are defined for the purpose of this Manual.

Conventional Supervisory Control

A custom-designed group of selector switches, push-buttons, indicators and electronic circuits connected by a wiring harness and packaged in completely integrated assemblies for installation at the central and remote stations. These stations are specifically designed and wired for the specific application. The operation and performance is fixed by the wiring, which has led to the use of the term "hardwired" control.

Computer Control

A digital computer with standard logic, memory, and wiring, installed at a central station. The customizing for a particular application is done by a list of instructions and programming, which are magnetically stored in the machine. This electronics programming gives rise to the term "softwired" type for its particular application.

Either of these two classes of electronic control systems allows the operation of remote equipment from the point of central control. The central station may have the data logging, data display and other data handling options. Both require essentially the same communication means. An operator at a control center could not generally tell whether controls are handled by a softwired computer or a hardwired conventional supervisory control system. There are a number of ways in which these two classes of equipment may be implemented. Four general techniques to consider are:

1. Conventional Supervisory;
2. Computer On-Line Control;
3. Conventional Supervisory with Off-Line Computer Monitoring; and
4. Computer On-Line with Conventional Supervisory Standby.

Hardwired conventional supervisory control equipment is a type that many operators have used for years. It has the advantage of having a low initial cost and central control may be implemented in step-by-step stages of development.

Softwired digital computer control can not only take over and perform all of the functions, but can also accomplish additional tasks beyond the ability of the conventional supervisory control.

The digital computer has no prewired control capability. Therefore a program must be written to customize the computer to a particular application before it is used in a control system. Programming the computer for control of remote stations requires special skills. A combination of waste water practice experience and computer application technique is required. Conceivably, the programming expense could exceed the cost of the conventional supervisory control system.

The value of the computer system lies in the additional benefits that fall into two general areas: (1) The flexibility of modifying and expanding the control system; and (2) the capability for data processing.

The value to the waste water management of the flexibility of modification and system expansion alone are not of sufficient importance to influence the selection of a computer. The control system for any specific remote station will normally remain static and unchanged after the initial requirements have been determined and successfully established, except for remote station expansion which could generally be taken into consideration during the initial implementation of the equipment.

4.7.2 Advantages of Data Processing

The capability for data processing, can be a most important benefit. These benefits alone may justify the higher cost and problems of program writing. Some of the benefits to be realized by data processing could be as follows:

1. Programmed data logging at periodic intervals;
2. Selective data logging, for example high repetition log on a particular variable for engineering study;
3. Computation and logging of quantities for selected time intervals;
4. Computation and logging of the summation of flows;
5. Computation and logging of inventory storage facilities;
6. Rate of change alarms on flows, levels, pressures, etc;
7. Deviation checking for off-normal conditions with alarms;
8. Computation and logging of equipment, operative status and running time;
9. Programmed or selected display of variables;
10. Programmed printout of instructions to operators;
11. Computation of load and system studies;
12. Storage of information and computation for billing purposes;
13. Preparation of data for storage in the form of punched card, punched paper tape, or magnetic tape;
14. Economic computations for operation guidance; and
15. Capability of actually performing as an element of the control scheme; that is, closing a control loop by performing its own control action.

Although the initial programming may be a relatively costly item, it should be a non-recurrent expense, and updating and changing to conform with system growth or altered data manipulation should be accomplished inexpensively.

4.7.3 Disadvantages of Data Processing

The disadvantages of each system are:

1. The conventional supervisory equipment:
   a. Must be customized for each particular application;
   b. Requires rewiring to change control patterns;
   c. Has limited capability of data handling;
   d. Lacks flexibility; and
   e. Maintenance costs may be high due to large number of components.
2. The digital computer control equipment:
   a. Costs more initially;
   b. Requires costly programming;
   c. Compounds the maintenance and service problem by requiring technical know-how in two additional technologies, one, the electronics of the computer and another, programming techniques, in addition to the electronics of the fixed wired conventional systems used at the remote stations.

4.7.4 Combining the Advantages of Supervisory Control and Digital Computer Control

In comparing the two techniques, the conventional supervisory control and the digital computer control, it is easily concluded that there would be considerable merit in initiating a construction program in which the advantages of both could be realized. This necessitates the use of both classes of equipment in either of two arrangements:

1. The conventional hardwired supervisory for remote control supplemented with a computer for monitoring and data handling;
2. The computer for on-line control and data handling, supplemented with the conventional supervisory equipment as standby for use when the computer is in down-time.

This second arrangement could be an outgrowth of a successful experience with the first. In this approach the hardwired conventional supervisory control would be purchased and installed in increments amenable to any overall program for converting the outlying station from manned to unmanned remotely controlled facilities. As the control system is expanded so are the computer facilities for monitoring and data handling, together or separately as the conditions and circumstances govern.

Advantages of the on-line availability of the supervisory system, together with the data handling capability of the computer, may then be realized in a gradual manner without an initial full commitment to either. This arrangement also has the advantage of allowing the computer to be taken off-line for program maintenance, problem solving or other uses for which the computer can be applied without disrupting the control of the remote stations.

The operations control center attendant would initially generate all control function messages to remote stations by manipulation of switches or push-buttons at his dispatcher's panel or console. The computer could monitor all messages going out to remote stations and all remote equipment status and remove measurement data being received from remote stations. The computer could therefore "listen-in" and be instructed to interrogate, check for limits and off-normal conditions, process and log the measurement data and cause whatever printouts including alarming and instructions the programming diagnostics would provide. Ultimately the computer might be programmed and interfaced with the supervisory equipment to exercise a certain amount of logical and routine control. This latter degree of sophistication would be approaching the case of computer on-line control with the manual supervisory as standby.

For the management of sewerage systems, it seems appropriate to place emphasis upon the long-range establishment of an operations control center. The plan of development should not require, however, the initial investment for the procurement of supervisory or data handling capacity for functions that are not expected to be required for several years nor for those partially known or unknown requirements of the future.

System growth should not be projected too far into the future. Changes, not only in the design and technique of control and data handling but also of the system affect future requirements. Rather than forecasting and perhaps freezing the requirements, it is better to arrange for considerable flexibility and the possibility of gradual expansion.

Consoles and panels, for expample, should be procured for only those control and metering functions initially required without panel cutouts or blanked panel space for the indefinite future. Console and panel arrangements should be such that additional sections or modules can be procured and installed when required. Nor should the initial equipment be designed to preclude the feasibility of replacement or rearrangement of certain console or panel sections or operational groups to meet future changes of the controlled system or even the layout and arrangement of the operations control center.

If the ultimate needs for the control center were known, it would seem most logical to choose one class of equipment designed for the combined requirements of control and data handling. This is not feasible. Plans should be prepared for the gradual implementation of both the conventional supervisory control equipment for remote control and the digital computer for monitoring and data processing.

4.8 Activation Equipment

Activation equipment refers to the power operators for regulator devices. Self-powered regulators such as floats and hydraulic cylinders, have been described in 2.7, 2.9, 2.10 and 2.11.

Electric motor operating regulating devices have been quite successfully employed on open-close type regulators and have been arranged for inching controls for intermediate positioning. Intermediate positioning control schemes have been arranged by using a series of limit switches and timers. In addition to the problems encountered with electrical equipment, the problem of loss of power is always of concern since this is most likely to occur during a storm which is precisely the period during which the regulator is most likely to function.

Recent development of electric motor operators for modulating or throttling control of valves, bring to the user a new and more appropriate drive unit for regulators. These drive units use low voltage, direct current motors with direct current power derived from silicon controlled rectifiers powered from the standard alternating current power sources. Small direct current batteries, similar to car or truck batteries, may now be used as standby power for regulator operation during power failures. These new motor designs can be controlled directly by presently available electronic instruments.

In the past, reversing contactors were required for throttling control of the standard motor. It was the reversing contactor, not the motor, that could not withstand continued reversing duty. The new motor designs eliminate the reversing contactor and continuous regulator control is possible. Gates, for example, can be controlled automatically to maintain a certain water level; they can be made to "hunt" in direct or indirect relation to the rise and fall of water level within a given band width; or they may be remotely positioned at any point within their full travel by a remote set point signal from a central control station. Gate position and water level, can be telemetered to the control station over the same control line. New motor operators and electronic instruments are small, allowing them to be placed in enclosures which protect them from exposure to adverse conditions. This new equipment, after it has been placed in service should prove to be of considerably less trouble and prove, to be less expensive to maintain. However, its initial cost will be more than the cost of conventional equipment.

An example of a design problem using total system control is presented in Section 7.

SECTION 5

PRACTICES FOR IMPROVED OPERATION AND MAINTENANCE OF REGULATORS AND THEIR APPURTENANCES

CONTENTS

Page

5.1 General

Satisfactory operation of combined sewer overflow regulator facilities depends to a large extent on adequate, regular inspection and maintenance. The purpose of this is twofold: First, to locate and correct any operational failures; and second, to prevent or reduce the probability of such failures.

5.2 Common Causes of Failure

Some of the factors causing failure as related to regulator types are as follows:

1. Static regulators
   a. Clogging
   b. Silting
2. Dynamic-semi-automatic
   a. Clogging
   b. Silting
   c. Sticking (lack of lubrication)
   d. Parts failure
   e. Corrosion
3. Dynamic-automatic
   a. Clogging
   b. Sticking (lack of lubrication)
   c. Parts failure
   d. Power failure
   e. Water pressure failure in float-actuated, hydraulically operated units

Of these factors, clogging is the principal offender. It affects all types of regulators to some extent and is practically impossible to eliminate entirely. Silting affects most regulators, but it can be controlled by regular flushing of the regulator station by the maintenance crew. The other factors apply to mechanical, electrical, or hydraulic types of regulators and their effects can be eliminated or minimized by proper inspection and maintenance.

5.3 Frequency Of Inspection Required

The susceptibility to clogging, to an important degree, determines the required frequency of regulator inspection. Several things affect this susceptibility. They include the type and size of regulator, the size of the combined sewer, the size of the connection to the interceptor, and the quantity and quality of the combined sewage.

Experience has shown that regulators of the orifice type, or which depend on an orifice for operation, particularly the horizontal orifice and leaping weir, readily clog, especially when the orifice is small.

Horizontal orifices, or drop inlets, protected by grates appear to be more subject to frequent clogging than any other type of regulator. Even daily inspection and cleaning may not be adequate to insure proper operation of this type of regulator.

Practice in the jurisdictions included in the National Investigation varies from daily or more frequent inspections to as few as three per year. The average number of inspections is approximately 70 per year.

Inspection must be as frequent as required to keep the regulators in as continuously operable condition as practicable. In general this will require an inspection schedule of at least each week and after every storm. Small orifices and drop inlets with grates will require more frequent inspection. It is recommended, however, that no regulator be inspected less frequently than twice per month and after each storm.

Experience will indicate which regulators require more frequent attention than others. The schedule should be adjusted to meet local or changing conditions. In this way maximum efficiency of operation will be achieved with minimum use of personnel.

5.4 Recommended Maintenance Program

The regulator chamber should be cleaned after every storm and more frequently if necessary to maintain satisfactory working conditions in the chamber.

For all types of regulators, each visit should include a visual inspection of the regulator and removal of any debris preventing or tending to prevent its operation. Preventive maintenance programs recommended for the various types of regulators are as follows:

1. Static Regulators
   a. Orifices

      Orifices clog frequently. Maintenance equipment should include hooks, sewer rods, and scoops, so that as much clearing of debris as possible may be effected from the ground surface. The regulator chamber may then be flushed out, also from ground surface.

   b. Drop Inlets and Leaping Weirs

      Grates protecting drop inlets should be checked to be sure they have not been damaged or weakened by corrosion. Inlets, particularly large ones without gratings should be fitted with grates or guard rails for the protection of the maintenance crew, as well as prevention of the entrance of large objects. Where blockages are excessive the gratings should be replaced by ones with larger openings. Leaping weir plates must be lubricated and adjusted semi-annually to prevent "freezing."

c. Side-Spill Weirs

Weir crests should be inspected for damage and be repaired promptly.

d. Manually-Operated Gates

Manually operated gates should be operated on a regular basis through the full range from the open to closed position and reset at the proper opening. The floor stand, if any, operating stem and guides should be freed of corrosion and be well lubricated.

2. Dynamic Regulators

a. Float-Operated Gates

If possible float-operated gates should be operated through a complete cycle. Float wells should be cleared of deposits of sand or sludge and all accumulations of debris should be removed from the float and float well. Chains and gears should be cleaned of rust and other deposits and thoroughly lubricated. All parts of the mechanism should be examined for wear or corrosion and, if necessary, promptly replaced or repaired.

b. Tipping Gates

Tipping gates should be checked to be sure they move freely on the pivot shaft. Adequate lubrication of the bearings is essential. In some cases it may be advisable to replace existing shafts and bearings with stainless steel shafts and bronze bearings.

c. Motor-Operated Gates

Motor-operated gates should be operated through the full range from open to closed position and reset at the proper opening. Where remote control is provided, the cycle should be run through, using the remote controls while the maintenance crew observes the operation and checks the final setting of the gate. Water level indicating and transmitting equipment should be checked to insure that it is functioning properly and measuring water levels accurately. All equipment should be inspected for signs of wear or corrosion, repaired or replaced, if necessary, and properly lubricated.

d. Cylinder-Operated Gates

If possible, cylinder-operated gates should be operated through a complete cycle. Float wells should be cleared of deposits and all accumulations of material should be removed from the float and float well. Strainers on the water supply line should be cleaned and inspected. Water supply lines, valves and cylinders should be inspected for leakage; and the pressure available at the cylinder under all operating conditions should be checked. Water level sensing equipment on hydraulically-oil-operated gates should be checked to insure that it is functioning properly and accurately. All equipment should be inspected for signs of wear or corrosion, repaired or replaced, if necessary, and properly lubricated. Cross-connection hazards should be detected and corrected to prevent pollution of public water supplies.

5.5 Personnel Requirements

Maintenance of regulators should be carried out by crews of three to five men, depending on the type and complexity of the regulators used. A minimum crew of three men is recommended in order that one man may remain on the surface while two men enter the chamber.

For simple regulators, three-man crews with one foreman to direct several crews should be satisfactory. Where remote controls, water level sensing devices and motor-operated gates are used, a crew of five men, including a technician and foreman may be required.

The number of crews required will depend on the number and types of regulators and the frequency with which they must be inspected.

5.6 Equipment Needs

Adequate equipment should be provided for the safety and efficiency of activities of the maintenance crew. The following items of equipment are considered necessary:

a. A 1½-ton panel truck with a two-way radio, winch and A frame

b. 110-220 volt portable generator

c. 1 and 2-hp submersible pumps

d. One 1½-hp blower unit

e. Various chains, ropes, hoses, ladders, pike poles, sewer hooks, sewer rods, chain jacks, tool kits, etc.

f. One oxygen deficiency meter, one explosimeter, and one H_2 detection meter, safety equipment, helmets, harnesses, first aid kits, danger flags, signs, barricades, life jackets, flares, gas masks or air packs, gas detector lamps, fire extinguishers, extension cords, rubber jackets, pants, boots, waders, etc.

g. Spare parts.

5.7 Safety Precautions

Precautions necessary to protect the maintenance crews from the hazards in the sewers and regulator chambers and from traffic are relatively uniform throughout the country. The following instructions, issued to the crews in Philadelphia, are typical:

1. Truck should be parked so as not to obstruct traffic but, if possible, should be used to protect men working near the open manhole. If truck is used for this purpose, suitable flashing lights must be used on the truck.
2. Warning cones, flags, signs, and lights should be used to make areas safe for both vehicle and pedestrian.
3. Manhole cover should be raised with a safe tool and bar placed under it so that it can be rolled to one side.
4. A manhole guard should be placed around the open manhole.
5. The air in both sewer and chamber should be checked for explosive mixtures and hydrogen sulfide. Oxygen deficiency should be checked.
7. If there is an indication of gases, the portable blower should be used to clear the area.

In addition to the above safety precautions it is considered essential that at least one man remain at the surface at all times to summon or render assistance in the event of an accident.

5.8 Maintenance Costs

The cost of maintaining sewer regulators, as reported in the National Survey, varies widely. In most cases the reported expenditures are probably not adequate to maintain the regulators in completely satisfactory condition. The annual cost per regulator required to conduct a satisfactory maintenance program is estimated to be as follows:

Description	Annual Cost per Regulator*
Vertical orifice or siphon	$ 600 – 800
Leaping weir	700 – 900
Drop inlet	1200 –1500
Side-spill weir	400 – 500
Manually operated gate	900 –1100
Float-operated gate	1100 –1200
Tipping gate	1100 –1300
Cylinder operated gate	1200 –1300

* From Report, Section 5

5.9 Records and Data Analysis

Complete records should be kept of all inspection and maintenance work. The time and date of each inspection should be recorded together with a description of the condition of the regulator and the work performed. The number of man-hours spent at each regulator should be noted.

The data obtained should be tabulated for each regulator and summarized for each type of regulator. These records will quickly reveal any regulators which require excessive maintenance or are out of operation with unusual frequency. The causes should then be investigated and, if possible, corrected.

The records also will provide the data needed to compare the cost and efficiency of different types of regulators for guidance in the design of new regulators or the remodeling of existing regulators.

SECTION 6

DESIGN AND LAYOUT, AS INFLUENCED BY OPERATION AND MAINTENANCE – TYPICAL CRITERIA AND DETAILS WITH RESPECT TO OPERATIONS AND MAINTENANCE

CONTENTS

6.1 Typical Layout Criteria

6.1.1 General

The layout of a regulator station should meet two criteria: The first, based on the hydraulic requirements; and the second, based on the operation and maintenance requirements. Very often the designer gives little attention to operating and maintenance requirements, with the result that the regulator fails to function properly due to lack of adequate maintenance. Hydraulic design principles have been outlined in Section 2. This Section considers the layout from the viewpoint of operation and maintenance.

6.1.2 Location

The designer may have little choice with regard to the location of the regulator. Regulators often must be located on existing combined sewers. Where the area is highly developed and there is no choice except to place the regulator station within the street right-of-way. If the street is a cul-de-sac and terminates at the water's edge it may be possible to fence off the end of the street for the regulator site. Where areas are partially developed, it may be possible to relocate the combined sewer so as to place the regulator on a site other than the traffic right-of-way. For maintenance purposes and for operator safety this is most desirable. If this is not possible, access to the facility should preferably be from the rear of the curb in order not to block traffic while routine maintenance is being performed.

6.1.3 Access

Separate access should be provided to each chamber of the regulator station. This is necessary when the chambers are small or the maximum level of the sewage in the chamber is near the ground surface.

In large chambers where the depth permits, access to the diversion and tide gate chambers may be combined.

Access to regulators located in streets is made through conventional manhole shafts with a vertical ladder or with manhole steps set 12 inches on centers.. If the regulator is deep, stairs should be used at a reasonable level below the ground surface.

When the regulator is located off the street, consideration should be given to alternate means of access rather than the standard manhole. If there is objection to a structure extending above ground, access can be provided by a floor door or hatch and a ship's ladder. A ship's ladder is a fixed inclined ladder with an angle to the horizontal of beteen 40 and 56 degrees. The minimum width of tread between stringers should be two feet. Ladders steeper than 56 degrees should not be used.

Where there is no objection to a superstructure, stairs can be provided. This increases the length of superstructure opening to 11 feet and requires a superstructure approximately 13 feet long, 5 feet wide, and 8 feet high. Details of such a stairwell are shown in Fig. 6.1.3. If a superstructure is required for electrical equipment the stairwell superstructure may be built adjacent to its exterior wall.

Spiral stairs should be considered where space is not available for standard stairs. These are constructed in various diameters, from 4 feet, considered a minimum for ease of access, to 6 feet or more depending on the requirement. They are usually constructed with either 12 or 16 treads to a complete circle. On a 12-tread circle, 9-inch risers will provide 6 feet 9 inches of headroom, and on a 16-tread circle 7-inch risers will produce 7 feet of headroom when calculated on the basis that three-fourths of the vertical height of a full circle is required for free passage.

6.1.4 Light, Heat and Ventilation

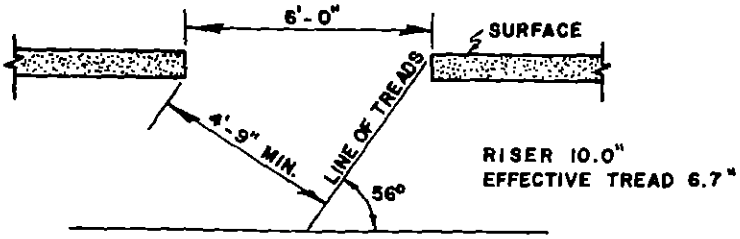
As a rule, insufficient consideration is given to light, heat and ventilation in regulator chambers of average size, particularly when no electric power is required for operation of the regulating device.

Portable lamps are usually used for lighting purposes. When the chambers are large, at least two manhole openings should be provided for each chamber for adequate light and ventilation. If the regulator is located below the point of access and is properly fenced, roof gratings can be used to increase light and ventilation. Whenever electric power is available at the regulator chamber, provision for electrical lighting in all parts of the regulator station is normal.

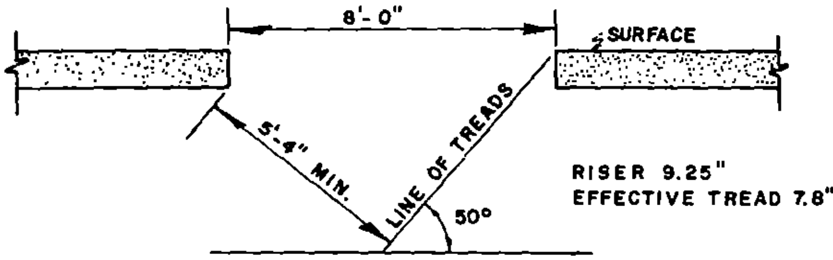
Heating is not considered necessary in underground chambers for the comfort of personnel. However, when dehumidifiers are used to prevent corrosion of electrical equipment, heating is sometimes provided to prevent freezing of the dehumidifiers and to reduce the relative humidity. Superstructures, if used, should be heated.

Shallow regulator stations using static regulator devices requiring little attention can be adequately ventilated by use of portable blowers. Such chambers should be tested for flammable gas or oxygen deficiency before entering. In deep chambers tests also should be made for the presence of carbon monoxide and hydrogen sulfide. Where mechanical equipment is used consideration should be given to the installation of ventilating equipment. Such ventilating equipment is considered essential for wet wells in sewage pumping stations. Present

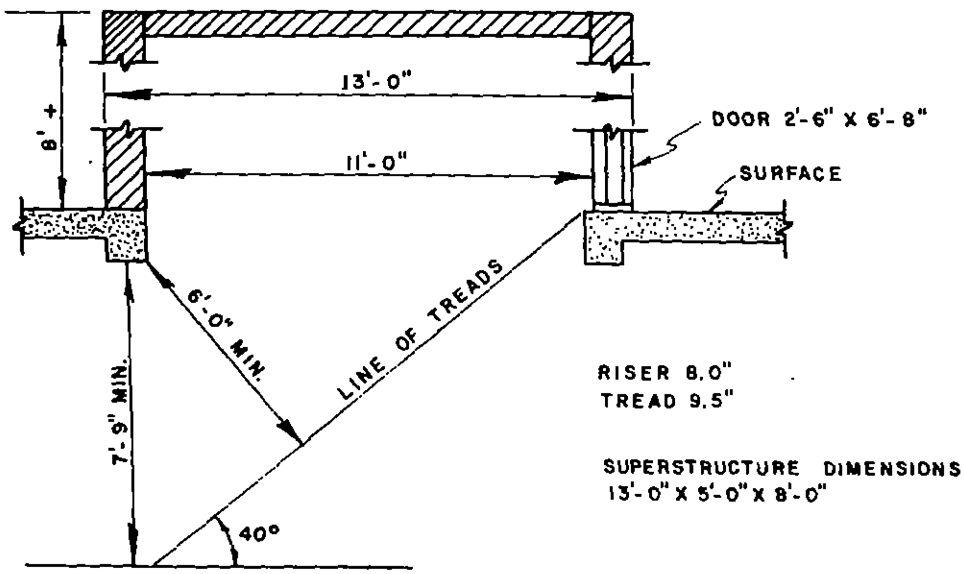
FIGURE 6.1.3



SHIP'S LADDER WITH 2'-6" X 6'-0" DOOR



SHIP'S LADDER WITH 2'-6" X 8'-0" DOOR



STAIRWAY WITH SUPERSTRUCTURE

ACCESS STAIRS

recommendations for such use by health authorities ("Recommended Standards for Sewage Works." Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, 1968) include: (1) Provide at least 30 complete air changes per hour for intermittent ventilation; (2) interconnect intermittently operated ventilating equipment with the lighting system; and (3) introduce fresh air into the wet well by mechanical means. The recommendations for pumping station wet wells, noted above, should be equally applicable to regulator chambers containing mechanical equipment and requiring frequent inspection.

6.1.5 General Features

The designer should visualize all possible activities of maintenance personnel and attempt to provide adequate and convenient facilities in which they can perform their duties. Walks or platforms, preferably above the maximum sewage level, should be provided so that all parts of the regulator station can be reached and so that the inlet and outlet sewers can be observed and are readily accessible. Benches for access landings should have a minimum width of 1½ feet. Headroom should be at least 6½ feet.

Guard rails should be provided around all openings or sudden drops. However, officials of one city interviewed in the National investigation stated that they generally do not use protective railings in the regulator chambers since the staff feels that reliance on a railing which may fail due to corrosion is more hazardous than the omission of the railing. However, this city uses railings of structural steel, encased in concrete, to prevent failure due to corrosion at regulator stations that are particularly hazardous and where a fall might mean death or serious injury.

Cast iron stop plank guides should be provided to shut off or divert flow to, or from a channel when required for maintenance purposes.

6.1.6 Gates

The sluice sizes available from one manufacturer are shown in Table 6.1.6. Normally the smallest size used in a regulator chamber should be 12 by 12 inches.

When a cylinder-operated gate is activated by water pressure the gate size is generally limited to a maximum of nine square feet. The size of gate when oil pressure is used is not limited.

A shaft and ground surface opening should be provided over each gate. The dimensions of this opening should be at least one foot greater in each direction than the overall dimensions of the gate, to allow quick, problem-free operation or removal.

6.1.7 Float Well

The float well should have minimum dimensions of three feet square. The bottom of the well is set above the invert of the adjacent channel and connected thereto with a 12-inch wide passage or telltale. The telltale should be aimed downstream from the float well to prevent floating solids from entering the well or plugging the telltale.

6.2 Materials

6.2.1 Metals

The best of the bronzes for corrosion resistance and strength is silicon bronze. This is a very high copper, zinc-free bronze. Manganese bronze castings and extrusions wear well. They are used for valve seats and operator stem nuts for this reason. Among the stainless steels, the 18-8 chromium-nickel content percentage respectively endures best. Types 303, 304, and 305 are used for valve stems, studs, nuts and bolts. Type 326 stainless steel is especially good in sea water and less costly than monel which also gives excellent service in salt water. Heavy body castings are usually grey iron castings, conforming with ASTM specification A126, Class B. However, in highly corrosive applications, Ni-Resist Type 1A has been used successfully. This is a trade name of International Nickel Company for an iron-casting with the following percentage composition: 14% nickel, 6% copper, 2½% chromium. Both cast iron and wrought iron are customarily coated with a hot coal-tar enamel in accordance with AWWA Specification C203. Bronze, stainless steel and monel are not usually coated.

Sluice gates generally should conform to AWWA Standard C501. This standard also covers sluice gate operating mechanisms of the manual, electric-motor and hydraulic-cylinder types. The latter type is oil operated at 2000 psi working pressure. The Suma Standard, Sect. 103, states that the purchaser may specify other operating media or pressures, as desired. One manufacturer has suggested four combinations of materials for sluice gates for use under various conditions. These combinations are shown in Table 6.2. Combination No. 1 which meets AWWA Standard C501 is not considered satisfactory for use in raw sewage service because it contains naval bronze. De-zincification, where zinc is dissolved from bronze leaving a weak, porous material, can occur with naval bronze in contact with either acid or alkali fluids. The low zinc content of phosphor or silicon bronze enables these alloys to resist de-zincification. Material Combination No. 3 would provide

TABLE 6.1.6

SLUICE GATE SIZES

Size of Gate Inches		Area of Clear Opening Square Feet	Size of Gate Inches		Area of Clear Opening Square Feet	Size of Gate Inches		Area of Clear Opening Square Feet
Rectangular Width X Height	Circular Diameter		Rectangular Width X Height	Circular Diameter		Rectangular Width X Height	Circular Diameter	
	6	.1964	36 x 18		4.50	66 x 72		33.00
6 x 6		.2500	36 x 24		6.00		72	28.27
	8	.3491	36 x 28		7.00	72 x 42		21.00
8 x 8		.4444	36 x 30		7.50	72 x 48		24.00
	10	.5454	36 x 36		9.00	72 x 60		30.00
10 x 10		.6944	36 x 42		10.50	72 x 72		36.00
	12	.7855	36 x 48		12.00	72 x 84		42.00
12 x 12		1.000	36 x 60		15.00	72 x 96		48.00
12 x 18		1.500	36 x 72		18.00		78	33.18
12 x 20		1.667	36 x 84		21.00	78 x 78		42.25
12 x 24		2.000		42	9.62	78 x 96		52.00
	14	1.069	42 x 24		7.00		84	38.48
14 x 14		1.361	42 x 27		7.88	84 x 36		21.00
	15	1.227	42 x 30		8.75	84 x 60		35.00
15 x 15		1.562	42 x 36		10.50	84 x 72		42.00
	16	1.396	42 x 42		12.25	84 x 84		49.00
16 x 16		1.778	42 x 48		14.00	84 x 96		56.00
16 x 24		2.667	42 x 60		17.50	84 x 108		63.00
	18	1.767	42 x 72		21.00		88	42.20
18 x 12		1.500		48	12.57		90	44.18
18 x 18		2.250	48 x 27		9.00		96	50.26
18 x 24		3.000	48 x 30		10.00	96 x 48		32.00
18 x 36		4.500	48 x 36		12.00	96 x 60		40.00
	20	2.182	48 x 48		16.00	96 x 72		48.00
20 x 20		2.778	48 x 54		18.00	96 x 84		56.00
20 x 24		3.334	48 x 60		20.00	96 x 96		64.00
20 x 36		5.001	48 x 72		24.00	92 x 120		80.00
	21	2.405	48 x 84		28.00	96 x 144		96.00
	24	3.142	48 x 96		32.00		102	56.75
24 x 12		2.000	48 x 108		36.00		108	63.62
24 x 18		3.000		54	15.90	108 x 48		36.00
24 x 24		4.000	54 x 48		18.00	108 x 60		45.00
24 x 30		5.000	54 x 54		20.25	108 x 108		81.00
24 x 36		6.000	54 x 72		27.00		120	78.55
24 x 48		8.000		60	19.64	120 x 42		35.00
24 x 60		10.000	60 x 36		15.00	120 x 72		60.00
	30	4.909	60 x 48		20.00	120 x 84		70.00
30 x 24		5.000	60 x 60		25.00	120 x 96		80.00
30 x 30		6.250	60 x 72		30.00	120 x 120		100.00
30 x 36		7.500	60 x 84		35.00	120 x 190		158.33
30 x 48		10.000	60 x 96		40.00	144 x 48		48.00
30 x 60		12.500		66	23.76	144 x 144		144.00
	36	7.068	66 x 66		30.25			

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TABLE 6.2

SLUICE GATE MATERIALS

Material Specifications:

CAST IRON	A 126, Class B or C
AUSTENITIC GRAY IRON CASTING (Ni-Resist)	A 436, Type 2 or 2b
STAINLESS STEEL (Seating Faces and Anchors)	A 276, Type 302 or 304
MONEL (Faces and Fasteners)	B 164, Class A or B
MANGANESE BRONZE (Lift Nuts and Wedges)	B 147, Alloy 8A
NAVAL BRONZE (Faces and Stems)	B 21, Alloy B
PHOSPHOR BRONZE (Faces)	B 139, Alloy A
SILICON BRONZE (Fasteners)	B 98, Alloy A, B or D
SILICON BRONZE (Castings)	B 198, Alloy 12A
STAINLESS STEEL (Fasteners)	A 320, Grades B8 or B8F (Bolts) A 194, Grades 8 or 8F (Nuts)
STAINLESS STEEL (Stems and Anchors)	A 582, Type 303

Material Combinations:

Gate Part or Item of Assembly	#1 Material Combination	#2 Material Combination	#3 Material Combination	#4 Material Combination
WALL THIMBLE	Cast Iron	Cast Iron	Cast Iron	Ni-Resist
GATE ASSEMBLY				
FRAME AND SLIDE	Cast Iron	Cast Iron	Cast Iron	Ni-Resist
SEATING FACES	Naval Bronze	Stainless Steel	Phosphor Bronze	Monel
YOKE (NRS ONLY)	Cast Iron	Cast Iron	Cast Iron	Ni-Resist
SIDE WEDGE BLOCKS	Cast Iron	Cast Iron	Cast Iron	Ni-Resist
CONTACT FACES	Naval Bronze	Stainless Steel	Phosphor Bronze	Monel
SIDE WEDGES	Manganese Bronze	Stainless Steel	Silicon Bronze	Monel
TOP AND BOTTOM WEDGES	Manganese Bronze	Stainless Steel	Silicon Bronze	Monel
FASTENERS	Silicon Bronze	Stainless Steel	Silicon Bronze	Monel
FLUSH BOTTOM ASSEMBLY				
STOP PLATE AND RETAINER	Cast Iron	Cast Iron	Cast Iron	Ni-Resist
STEM ASSEMBLY				
STEM	Stainless Steel	Stainless Steel	Stainless Steel	Monel
STEM BLOCK	Manganese Bronze	Ni-Resist	Silicon Bronze	Ni-Resist
STEM SPLICE	Stainless Steel	Stainless Steel	Stainless Steel	Monel

compatible materials for this condition. Combination No. 2 would also satisfy this condition.

Ammonia-bearing fluids such as raw sewage may cause stress-corrosion cracking to which copper based alloys are extremely susceptible. Since the 300 Series of stainless steel is not affected by stress corrosion cracking, the No. 2 Material Combination replaces with stainless steel all bronze gate parts subject to high stress. Combination No. 4 is intended only for salt or brackish water installations and combines the most corrosion-resistant materials.

Piping for air, water or oil should be corrosion-resistant. A suitable pipe for this purpose is seamless red brass pipe meeting ASTM specification B43. Suitable fittings for this pipe are copper-base alloys meeting ASTM specification B30, Alloy 4B.

Manhole steps usually are made of cast iron or aluminum. Vertical ladders usually are made of galvanized steel or aluminum. Ship's ladders can be fabricated with either galvanized steel or aluminum stringers and either cast iron or cast aluminum abrasive treads. Spiral stairs also can be obtained with cast iron or cast aluminum treads. Normally the center column is a 3 to 4-inch-diameter steel pipe; for regulator use the center column should be stainless steel. Aluminum used in the foregoing is usually specified to be 6061-T6, 6063-T5, 6063-T6 and 6063-T832.

6.2.3 Elastomers and Gasket Materials

The most commonly used elastomer is Neoprene. Neoprene is a copolymer of butadiene and acrylic nitrile. It has good resistance to hydrocarbons and ozone and resists air-hardening. Nitrile and a blend of nitrile and polyvinyl chloride also have good resistance to the sewage atmosphere. Natural rubber deteriorates in sewerage applications and is not recommended. Gaskets and packing should be made of asbestos, teflon coated asbestos or tallow lubricated flax.

6.2.4 Electrical

Motors located in underground chambers or in above-ground chambers into which sewer atmosphere may escape should be explosion-proof conforming to National Electric Code Article 500 for Class I, Group D, Division I locations. Wires should be in conduits of corrosion-resistant materials such as polyvinyl chloride.

6.2.5 Plastics

Although plastics and plastic-coated metals have not been used to any appreciable extent in combined sewage regulator installations, they offer considerable promise for the future. Coatings such as epoxy, vinyl, nylon, and celloplosic applied by the fluidized bed process all endure well in sewage service. They are quite abrasion-resistant, an important consideration as combined sewage contains much grit. These coatings applied to steel and aluminum offer maximum corrosion resistance, coupled with good strength characteristics.